MUSHROOM
RESEARCH
STATION
YAXLEY
PETERBOROUGH

# REPORT
## *for year* 1949

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# REPORT
## *for year* 1949

YAXLEY, PETERBOROUGH

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# PREFACE

by the Chairman, Lt.-General Sir Oliver Leese, Bart., K.C.B., C.B.E., D.S.O.

I was very privileged to be the Chairman of the Mushroom Research Association on its change over to the new status. I would like first of all to pay my tribute to the original members whose pioneer work laid the foundations for the excellent station which is now available to mushroom growers throughout the country. A great deal of forethought and energy was put into this station quite apart from considerable sums of money, and I feel mushroom growers throughout the country will always be indebted to those pioneers of our industry for all that they did.

I feel I should next draw attention to the courtesy and consideration shown by the Ministry of Agriculture during the negotiations in which we settled how the new status of the Association should be organized. Mr. C. E. Hudson and his colleagues showed every consideration for our views and it is largely thanks to their endeavours and understanding that we have started off in such a smooth and efficient manner. We were confronted with the formidable task of raising £2,500 in order to provide our share of the total sum of £5,000 necessary for the maintenance of the Research Station for 1949. The response was on the whole very gratifying for the first year. A very large number of growers subscribed but there are still too many who have not yet done so, and I do take this opportunity to appeal once more to every mushroom grower to give what he can, as I am a firm believer in the fact that every grower sooner or later is bound to benefit considerably from the results of this research. There was a very fine response too from market wholesalers and also from sundriesmen connected with the mushroom industry, and I would like in particular to mention the generosity of Messrs. Broome and Green, Francis Nicholls, and Messrs. Darlington. The splendid response of so many people connected in many different ways with the mushroom industry is in itself a great tribute to our industry, and is yet another example of the cordial relations existing amongst mushroom growers and those allied to the trade.

On resigning my chairmanship at the end of 1949, I would like in particular to thank Dr. Edwards and his staff for the splendid work they have done and for all the assistance which they have given me as chairman during this last year. I have complete confidence in the future of the Research Station and I take this opportunity to wish the new Chairman, Committee and Staff of the Research Station all success in 1950.

# STAFF

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MISS I. WARMAN
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J. HOLLAND—to 4th February, 1949
E. SIMPSON—to 11th February, 1949
MISS M. YARROW—from 29th August, 1949

**Secretary :**

MISS J. HILL—to 12th August, 1949
MRS. M. CROWSON—from 31st October, 1949

**Foreman :**

G. R. BROWN

**Assistant :**

D. EATON—to 12th August, 1949
MRS. F. REEVES—from 8th October, 1949

# GENERAL REPORT

The year under review saw several important changes in the work of the Research Station. The first of these was the transfer from private to semi-public management, bringing with it the duty to publish all results, and a greatly increased demand for advisory services from the 200 new subscribers.

Secondly there was a change in programme. Work on composting has continued, but will now include experiments on the best use of light manure such as that from racing stables which forms the bulk of the present supply. It now seems likely that some of this will still be available in regular supply for many years but the quantity and price remain to be seen.

Attention was also transferred to house treatments with experiments on the time of casing and systems of picking. The results of all these experiments are reported in detail in the section on Cropping Experiments, with a summary of the conclusions drawn from each experiment. It is enough to say here that they rounded off previous work on synthetic compost, cor firming some features previously based on a single experiment ; started a search for a cheaper source of organic nitrogen and showed the probable importance of casing time without determining what this should be.

Several new experimental designs were tried out and one considered to be an improvement was used for Experiment 11 and for two experiments started during the year and running on into 1950. One of these dealt with the addition of supplements to long straw horse manure and the other with composting time and peak heating of synthetic compost.

A land mark was the publication in April, just three years after laying the foundations of the laboratory, of a Report on Synthetic Compost, giving the formula of a complete activator. It has given promising results on the experimental scale and is now being tried by growers. Reports are as yet too scanty to establish its status, but some satisfactory crops have been obtained. The formula is reproduced later in this Report with directions revised as a result of more recent experience. It cannot be said too often or too emphatically that the directions are quite as important as the activator and must be followed in detail. A good activator badly used has no more chance of producing a crop than a bad one well used.

Another welcome advance was the use of Calor Gas Burners to peak heat the beds. This is described in detail on page 49, and peak heating by this, or any other means, is regarded as highly beneficial.

The main laboratory work in the Chemistry Department is still sampling and analysis of composts. Efforts are always being made to improve accuracy and for this purpose estimates of the errors and a search for their source must always be made. One of the main uses of these analytical results is to determine what happens to the raw materials put into a compost, particularly the total bulk of organic matter and the nitrogen. Analysis expressed as a percentage of the total dry weight

at each stage is misleading, because this weight is constantly changing as material is used up by bacteria, moulds and the mushroom. For this reason we used the quantity of mineral matter insoluble in acid as a basis for all analyses because it does not change appreciably whatever else happens in the compost. Much work has been needed to establish the soundness of this practice. When this was established it was found that there is appreciable variation between composts made from the same materials. Some of these may be due to variation between bales of straw. Sampling is particularly difficult early in composting, before the straw and activator are properly mixed, but samples taken later are more uniform. It is obvious that information about the loss of food material during composting and cropping is important. A study of the relation between this loss of organic matter during composting and during cropping with the corresponding losses of nitrogen in relation to stack temperatures and yields has led to the following conclusions :—

There is normally a loss of organic matter during composting and cropping due to its use as food for bacteria and fungi, other than the mushroom. If it is low during composting it is high during the cropping period.

There is also a loss of organic matter during cropping which is directly related to the mushroom crop picked as might reasonably be expected.

The total loss during the cropping period is made up of these two and either may predominate.

Within the range of temperatures covered in these experiments, the stack temperature had no effect on the yield.

Composts containing hide meal gave very low losses of organic matter during cropping, but the amount used by the mushroom was apparently normal, so presumably other organisms were very much less active in these beds containing hide meal.

Very interesting results were obtained in Experiment 11 on the effect of peak heating after various composting periods from 3-6 weeks. Compost from stacks which had been under-composted showed very big further changes in the bed during peak heating, whereas over-fermented compost showed relatively little change. The combined result of fermenting in the stack and during peak heating was very similar and this agrees with the close similarity in the yield of mushrooms.

Losses of nitrogen during composting were increased at very high composting temperatures (average temperature over 160° F.) There are losses of nitrogen from compost during cropping, some going into the casing soil, some, of course into the mushrooms, while a substantial amount is completely lost, presumably by bacterial denitrification. The hide meal showed lower losses by denitrification corresponding with the lower loss of organic matter. These observations have focused attention on the activities of other organisms in the compost during the cropping period. There is, at present, no direct evidence that they injure the mushroom crop, but they cannot be ignored and there is always the possibility that they use some food material which would otherwise be available for the mushroom.

One method of studying their activity is to add to compost in the laboratory substances which would allow growth of the mushroom but not of bacteria. Using certain dyes known to act in this way, tests have been started and the results are sufficiently encouraging to justify continuing these experiments.

With the approval of growers and of the Agricultural Research Council, work in the microbiology department is turning from compost to the study of diseases and competitors. Miss Duncan having joined the staff late in 1948, spent the first part of the year gaining experience of growing and examining diseased specimens before embarking upon a formal programme of research. Later in the year some pure culture experiments were started and an isolation cell was set up for trial with a view to direct infection of growing mushrooms without the risk of spreading disease in our cropping houses. This isolation cell is still on trial but it cannot be as good as a separate experimental disease house where trays of a reasonable size could be freely used. However, lack of funds at present prevents that desirable addition to our equipment.

One of the competitors needing most investigation is Truffle, and a series of experiments has been started to study the effect of various conditions in composting on its development. Preliminary observations show that wet compost encourages its growth, but it was not determined whether this was directly due to the extra moisture or, for example, to its effect in lowering the pH. This work will be continued.

This year in addition to the Departmental Reports we include several miscellaneous articles of possible interest and use to growers, yet falling outside the normal scope of our Research Programme.

Acknowledgements. As in previous years, we owe much to those growers who have given us their opinions and advice on various subjects, particularly the Directors of the Association, to Messrs. Noble Mushrooms Ltd., Mr. B. A. Noble, Mr. F. C. Atkins and to Mr. Angus Watson, as Secretary to the Association. We have also to thank the members of a sub-committee of the Agricultural Research Council, led by Professor F. T. Brooks, F.R.S., for their interest and advice in our programme, and Messrs. E. C. Fieller and A. M. Walker for advice on statistical methods.

# CROPPING EXPERIMENTS — R. L. Edwards

Three cropping experiments were completed during the year, similar in general purpose and design to those carried out in previous years. The development of a synthetic compost was continued and some attention was turned to a search for alternative source of organic nitrogen cheaper than dried blood. An earlier small scale experiment on the best time of composting was repeated using a whole house, and with additional heat supplied by portable Calor Gas burners, all the beds in one house were raised for the first time to peak-heating temperature. For the first time since our preliminary experiment with horse manure in 1946, variations in the management of beds in the house were introduced and work of this kind will probably form an increasing part of our programme in the next few years.

## Experiment 9

This experiment was designed to test a higher level of nitrogen than any previously used, to compare two levels of calcium, and to extend previous work on the best time for addition of superphosphate. Three superphosphate treatments were given—no addition at all, 38 lb. per ton of straw at stacking, and the same amount at the fourth turn when gypsum was added. All stacks were composted for five weeks and turned

**Table 1—Design of Experiment 9**

| | | | | | |
|---|---|---|---|---|---|
| Po or Ps or $P_F$ | × | $N_3$ or $N_4$ | × | $Ca_1$ or $Ca_2$ | |
| 3 | × | 2 | × | 2 | = 12 treatments |

**Table 2—Composition of Stacks in Experiment 9**

| | All stacks lb. | $N_3$ lb. | $N_4$ lb. | Po lb. | $P_F$ lb. | Ps lb. | $Ca_1$ lb. | $Ca_2$ lb. |
|---|---|---|---|---|---|---|---|---|
| **At Stacking** | | | | | | | | |
| Wheat straw (4 bales) | 360 | | | | | | | |
| Sulphate of potash | 2 | | | | | | | |
| Castor bean meal .... | 16 | | | | | | | |
| Gypsum .... .... | 14 | | | | | | | |
| Dried blood .... | | 64 | 75·5 | | | | | |
| Nitrochalk .... .... | | 0 | 11·5 | | | | | |
| Ground chalk .... | | | | | | | 8 | 16 |
| Superphosphate .... | | | | 0 | 6 | 0 | | |
| **At 4th turn** | | | | | | | | |
| Trace elements .... | T.E. | | | | | | | |
| Gypsum .... .... | 14 | | | | | | | |
| Superphosphate .... | | | | 0 | 0 | 6 | | |

weekly. The general design of the experiment is shown in Table 1 and the composition of the stacks in Table 2. These variations in composition had no effect on the stack temperatures, all the averages being between 147° F. and 149° F. The addition of phosphate at the fourth turn gave a slightly earlier crop, as shown in Table 3, but the difference was not statistically significant. The yields after 12 weeks picking are summarised in Table 4, they show that the optimum level of nitrogen has been reached at about 3 cwt. dried blood per ton of straw. There was no significant difference in yield between the two levels of calcium used.

**Table 3—Interval from spawning to first picking in Experiment 9**

| | days | s.e. |
|---|---|---|
| Po .... .... .... .... .... .... | 123 | |
| Ps .... .... .... .... .... .... | 126 | ± 8 |
| $P_F$ .... .... .... .... .... .... | 111 | |
| $N_3$ .... .... .... .... .... .... | 115 | |
| $N_4$ .... .... .... .... .... .... | 126 | ± 7 |
| $Ca_1$ .... .... .... .... .... .... | 120 | |
| $Ca_2$ .... .... .... .... .... .... | 121 | ± 7 |

**Table 4—Yields after 12 weeks picking**

| | Mushrooms/ sq. ft. | Oz./sq. ft. | Average size oz./mushroom |
|---|---|---|---|
| No phosphate .... | 6·5 | 8·0 | 1·23 |
| Phosphate at start .... | 4·7 ± 2·3 | 5·6 ± 2·4 | 1·20 |
| Phosphate at 4th turn | 10·3 | 13·3 | 1·29 |
| $N_3$ .... .... .... | 7·6 | 9·7 | 1·28 |
| $N_4$ .... .... .... | 6·7 ± 1·8 | 8·3 ± 1·9 | 1·24 |
| $Ca_1$ .... .... .... | 6·7 | 8·6 | 1·28 |
| $Ca_2$ .... .... .... | 7·6 ± 1·8 | 9·4 ± 1·9 | 1·24 |

The best average yield from a group of beds treated alike was 1·25 lb./sq. ft.

The results of the phosphate experiment are very interesting. No benefit whatever was obtained by putting in superphosphate when the stack was first made, but when added at the fourth turn it gave a substantial increase in the number of mushrooms and in the total yield. This was not merely a stimulating effect on fruiting because it persisted throughout the cropping period and was not accompanied by any fall in size of the mushrooms as one expects from a substance acting purely as a fruiting stimulant. Table 5 shows the regularity of the phosphate effect and demonstrates that the general productive level of the compost was

**Table 5—Effect of phosphate throughout cropping period, yields in separate 4 week periods**

| | Mushrooms/sq. ft. | | | Oz./sq. ft. | | | Average size, oz./mushroom | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4 | 4-8 | 8-12 | 4 | 4-8 | 8-12 | 4 | 4-8 | 8-12 |
| | weeks | | | weeks | | | weeks | | |
| No phosphate | 1·9 | 2·9 | 1·7 | 3·7 | 3·2 | 1·1 | 1·95 | 1·10 | 0·65 |
| Phosphate at start .... | 1·3 | 2·3 | 1·1 | 2·4 | 2·5 | 0·7 | 1·85 | 1·09 | 0·64 |
| Phosphate at 4th turn .... | 2·6 | 4·2 | 3·5 | 5·5 | 5·5 | 2·3 | 2·12 | 1·32 | 0·67 |

raised. Although the over-all effects of nitrogen and calcium were not significant there was a tendency, as shown in Table 6, for the two to react together, giving the best yields when both were present in the higher proportions. No observations were made on the duration of cropping as the house was emptied immediately after the 12 week picking period to make room for the next group of composts. The analysis of these composts is discussed in the Chemistry Report, but it may be noted here that action of the phosphate is not due to its effect on pH.

**Table 6—Details of nitrogen and calcium treatments**
All stacks with superphosphate added at 4th turn

| | Mushrooms/ sq. ft. | Oz./sq. ft. | Average size oz./mushroom |
|---|---|---|---|
| $N_3$ $Ca_1$ .... .... | 10·5 | 13·6 | 1·30 |
| $N_3$ $Ca_2$ .... .... | 7·5 | 8·7 | 1·16 |
| $N_4$ $Ca_1$ .... .... | 8·3 ± 4·6 | 10·6 ± 4·8 | 1·28 |
| $N_1$ $Ca_2$ ... .... | 14·8 | 20·4 | 1·38 |

## Conclusions

Increasing the nitrogen from 50 lb. (supplied as 400 lb. of dried blood per ton of straw) to 70 lb. by adding extra dried blood and nitrochalk, did not increase the yield in any way.

There was no difference in yields between composts containing 50 and 100 lb. ground chalk per ton of straw.

Adding superphosphate at stacking made no difference to the yield, but 38 lb. of superphosphate per ton of straw added at the fourth turn greatly increased the yield.

## Experiment 10

This experiment was arranged to test soluble hide meal as an alternative to dried blood, and the addition of nitrochalk to each of these organic materials; and to repeat the previous test on nitrochalk with sugar beet tailings (Table 7). In the test house two further treatments were introduced; a variation in time of casing and two different systems of picking. (Table 8). The best time for casing beds is one of the most controversial subjects in commercial practice. Beds in this experiment were cased 4, 14 and 24 days after spawning. The picking test was intended to follow up observations on the growth rate of individual mushrooms by comparing beds on which mushrooms were consistently picked before the veil opened with others on which the veil was always allowed to open before picking. The experiment was arranged in a confounded design which enabled more treatments to be introduced on a limited number of beds with little sacrifice of accuracy.

**Table 7—Composition of stacks in Experiment 10**

| | All stacks | Blood | | Hide | | Inorganic N + beet | |
|---|---|---|---|---|---|---|---|
| | | $N_3$ | $N_4$ | $N_3$ | $N_4$ | no potash | with potash |
| Straw | 270 | | | | | | |
| Superphosphate | 2 | | | | | | |
| Ground chalk | 3 | | | | | | |
| Gypsum | 10 | | | | | | |
| Castor bean meal | 7 | | | | | | |
| Potassium sulphate | | 2 | 2 | 2 | 2 | 2 | 10 |
| Dried blood | | 50 | 50 | | | 12 | 12 |
| Soluble hide meal | | | | 100 | 100 | | |
| Nitrochalk | | | 18 | | 18 | 38 | 38 |
| Sugar beet tailings | | | | | | 56 | 56 |
| **At 4th turn** | | | | | | | |
| Superphosphate | 3 | | | | | | |
| Gypsum | 7 | | | | | | |

**Table 8—Design of Experiment 10**

| Composts | Casing, days from spawning | Picking mushrooms |
|---|---|---|
| Dried blood $N_3$ level | | |
| Dried blood + nitrochalk to $N_4$ level | 4 | |
| Hide meal $N_3$ level | or | closed |
| Hide meal + nitrochalk to $N_4$ level | 14 | or |
| Mainly nitrochalk—N + beet tailings | or | open |
| Mainly nitrochalk—N + beet + potash | 24 | |

The maximum stack temperatures are given in Table 9. The hide meal composts came into crop first as shown in Table 10 and there was little difference due to the time of casing. Final yields are given in Table 11. They show that hide meal is nearly as good a source of nitrogen as dried blood, in fact the difference between these two was not quite statistically significant. The nitrochalk–beet tailings mixture was not quite as good as dried blood, even with the addition of potash. The effect of potash in this mixture is doubtful. Hide meal and similar materials are certainly worth further trial. There was no difference in yield between the two systems of picking.

**Table 9 –Mean Max. compost temperature in Experiment 10**

| | °F. |
|---|---|
| Dried blood $N_3$ .... .... .... .... | 154 |
| Dried blood $N_4$ .... .... .... .... | 145 |
| Inorganic N+beet .... .... .... | 144 |
| Inorganic N+beet+potash .... .... | 147 ± s.e. 4·5 |
| Hide meal $N_3$ .... .... .... .... | 151 |
| Hide meal $N_4$ .... .... .... .... | 153 |

**Table 10 –Interval from spawning to first picking in Experiment 10**

| **Compost** | days | |
|---|---|---|
| Dried blood—$N_3$ .... .... .... .... | 89 | |
| Dried blood—$N_4$ .... .... .... .... | 105 | |
| Hide meal—$N_3$ .... .... .... .... | 52 | |
| Hide meal—$N_4$ .... .... .... .... | 60 | |
| Inorganic N+beet .... .... .... | 96 | |
| Inorganic N+beet+potash .... .... | 109 | |
| **Cased** | from spawning | from casing |
| After 4 days .... .... .... .... | 86 | 82 |
| 14 days .... .... .... .... | 83 | 69 |
| 24 days .... .... .... .... | 87 | 63 |

The effect of casing time was very interesting. Late casing gave many more mushrooms, and although they were smaller, the final yield was greatest on the beds which were cased last. One of the reasons given for casing early is to get the maximum crop off the beds in a limited time. This experimental crop was a slow one, but the hide meal composts cropped in fairly good time and may give some indication of the results to be expected in commercial growing. Table 12 gives the yields up to 15 weeks from spawning for the two sets of hide meal composts separately. The average picking times in this period were $7\frac{1}{2}$ and $6\frac{1}{2}$ weeks. The Table shows that in this limited time even the earliest compost to start cropping gained no advantage from the early casing and the tendency was towards more mushrooms and a better crop if casing was delayed. It must be emphasised that this is only the result of one experiment and is not a proof that late casing is best under all conditions. It does not yet justify a general recommendation of any particular casing time. However, the very substantial differences produced strongly suggest that the time of casing can have a considerable

effect on yield, and that delaying casing until the spawn is really well established, possibly three weeks after spawning, is worth serious consideration. This point may be of great importance in connection with the tray system where a quick spawn run and early cropping are particularly important.

**Table 11—Final yields in Experiment 10**

| | Mushrooms sq. ft. | oz./sq. ft. | oz./Mushroom |
|---|---|---|---|
| Compost | | | |
| Dried blood $N_3$ .... | 27 | 20 | 0·72 |
| Dried blood $N_4$ .... | 21 | 16 | 0·75 |
| Hide meal $N_3$ .... | 22 | 17 ± s.e. 1·6 | 0.79 |
| Hide meal $N_4$ .... | 21 | 16 | 0·79 |
| Inorganic N+beet .... | 15 | 12 | 0·80 |
| Inorganic N+beet+ potash .... .... | 19 | 15 | 0·78 |
| Cased | | | |
| After 4 days .... .... | 16 | 14 | 0·90 |
| After 14 days .... .... | 20 | 15 ± s.e. 1·2 | 0·76 |
| After 24 days .... .... | 26 | 18 | 0·70 |
| Pickings | | | |
| Closed mushrooms .... | 21 | 16 | 0·76 |
| Open mushrooms .... | 21 | 16 ± s.e. 1·0 | 0·78 |

The best average yield from a group of beds treated alike was 1·75 lb./sq. ft.

**Table 12—Yields on hide meal composts in 15 weeks from spawning**

| Cased | Mushrooms/ sq. ft. | oz./sq. ft. | oz./Mushroom |
|---|---|---|---|
| $N_3$ 4 days after spawning | 10 | 10 | 1·08 |
| 14 ,, ,, ,, | 15 | 12 | 0·80 |
| 24 ,, ,, ,, | 23 | 12 | 0·53 |
| $N_4$ 4 ,, ,, ,, | 4 | 5 | 1·25 |
| 14 ,, ,, ,, | 5 | 7 | 1·33 |
| 24 ,, ,, ,, | 16 | 12 | 0·73 |

**Conclusions**

Soluble hide meal was not quite equal to dried blood as a source of nitrogen, but this and similar materials are worth further trial.

There was no difference in yield between beds picked exclusively for open and closed mushrooms.

Beds cased 24 days after spawning gave better yields than those cased after 4 and 14 days.

## Experiment 11

The main object of this experiment was to compare different composting periods from three to six weeks. It was arranged to provide also for varying treatments on separate beds in the house, but these were not applied so that the comparison between what would have been these experimental groups could be used to test the uniformity of the crop on larger groups of beds than have been available previously for this purpose. Uniformity becomes increasingly important as the main features of compost and management are established and smaller increases in yield have to be detected. The 24 composts made were arranged in six blocks of four stacks. The stacks were started at weekly intervals in adjoining bays of the turning shed so that the solid formation was always maintained, and they were moved as necessary when turning, to their final positions in the blocks. At filling, one stack in each block had been composted for three weeks, one for four weeks, one five weeks

**Table 13—Results of Experiment 11**

| | | | | |
|---|---|---|---|---|
| Composting period | 3 | 4 | 5 | 6 weeks |
| Interval from spawning to picking .... | 49 | 51 | 48 | 48 days |
| Av. yield in 4 weeks | 9 | 9 | 10 | 12 mushrooms/sq. ft. |
| | 0·6 | 0·6 | 0·7 | 0·7 lb./sq. ft. |
| | 1·08 | 1·07 | 1·14 | 0·97 oz./mushroom |
| Av. yield in 8 weeks | 32 | 31 | 38 | 37 ± 3·6 mushrooms/sq. ft. |
| | 1·5 | 1·5 | 1·7 | 1·7 ± 0·12 lb./sq. ft. |
| | 0·75 | 0·77 | 0·72 | 0·74 oz./mushroom |
| Av. yield in 12 weeks | 53 | 55 | 60 | 53 ± 5·0 mushrooms/sq. ft. |
| | 2·0 | 2·0 | 2·2 | 2·1 ± 0·15 lb./sq. ft. |
| | 0·59 | 0·58 | 0·58 | 0·63 oz./mushroom |
| Final .... .... .... | 61 | 65 | 68 | 59 mushrooms/sq. ft. |
| | 2·2 | 2·2 | 2·4 | 2·2 lb./sq. ft. |
| | 0·57 | 0·55 | 0·57 | 0·6 oz./mushroom |
| Duration of picking | 153 | 152 | 155 | 154 days |
| Range of yields at 12 weeks | | | | |
| maximum | 2·4 | 2·5 | 2·6 | 2·5 } lb./sq. ft. |
| minimum | 1·1 | 1·2 | 1·6 | 1·6 } |
| Co-efficient of variation .... .... | 16% | 15% | 10% | 11% |

The best average yield after 12 weeks from a group of three beds treated alike was 2·3 lb./sq. ft. and the corresponding final yield 2·8 lb./sq. ft.

and one six weeks. All stacks were turned weekly. There was a notable difference in appearance and texture as a result of these different composting periods. The straw bales were cut once and all stacks were made up with the Activator described in Bulletin No. 15 and elsewhere in this Report.

Previous experiments have been handicapped by the fact that the composts have not been peak-heated in the beds and for this experiment special measures were taken to overcome this difficulty. The use of Calor Gas burners is described elsewhere in this Report. They raised the temperature of the beds to 120° F. for about 24 hours. The results are shown in Table 13. The most notable feature is the greatly reduced variation between different beds on the same treatment, compared with previous experiments. This is shown by the co-efficient of variation which is very much smaller than any previously obtained, and by the smaller range between maximum and minimum yields. The dates of first picking were also much more uniform. There was no appreciable difference in average yield or time to crop between the different composting periods, but composts fermented for five and six weeks gave rather more consistent results than those fermented for three and four weeks. The analytical results described in detail in the Chemical Section of this Report, suggest that the peak-heating treatment is largely responsible for the smallness of the difference in yield. Although there was no control group of beds not peak-heated, the general trend of these results, considered with those previously obtained, strongly suggests that peak-heating is a very important part of the preparation of synthetic compost.

**Conclusion**

There was no appreciable difference in average yield between composts made for three, four and five weeks in the stack and then peak-heated in the beds at 120° F. for 24 hours.

Composts stacked for five and six weeks gave rather more consistent results than those stacked for only three or four weeks.

# CHEMISTRY DEPARTMENT—S. Burrows

During the past year attention has been directed towards determining the accuracy of the sampling methods, to confirming previous results and to studying in more detail, dry matter losses during composting, peak heating and cropping.

## SAMPLING

### 1. At the First Turn

In Experiment 11 four replicate composts prepared on different days were sampled in duplicate by the method outlined in the previous report and from these samples, after drying and grinding, duplicate sub-samples were taken for total ash and acid insoluble ash determinations. The variations found are given in Table 14. The analytical error,

**Table 14—Sampling Errors at First Turn**

| | Total ash | | Acid insoluble ash | |
|---|---|---|---|---|
| Mean of duplicate determinations on four composts. (% of dry matter) .... | 12·03 | | 6·28 | |
| | Standard error | Co-efficient of variation | Standard error | Co-efficient of variation |
| Analytical and sub-sampling variation | 0·28 | 2·3 | 0·154 | 2·5 |
| Sampling variation | 0·76 | 6·1 | 0·172 | 2·7 |
| Compost variation | 1·92 | 18 | 0·213 | 3·4 |
| Compost variation calculated from 23 stacks .... | 0·87 | 7·2 | 0·26 | 4·1 |

which also includes the error of sub-sampling the dried, ground compost was satisfactory in view of the known difficulty of obtaining reproducible figures when ashing plant materials. The sampling error is also satisfactory especially in the case of the acid insoluble ash figures which thus form a reliable basis for calculating dry matter losses. The higher sampling error calculated from the total ash figures may be due to the fact that the activators added have a high soluble ash content and were not yet well distributed by the first turn. All except one of the remaining compost stacks in this series were sampled at this stage but not in duplicate. The compost variation calculated from these samples was 7·2% for total ash and 4·1% for acid insoluble ash. These figures give a more accurate estimate of the variation between nominally replicate composts than those calculated from the four composts sampled in duplicate. The acid insoluble ash is derived mainly from silica in the

straw and soil adhering to the straw so that the estimate of the stack variation obtained from the acid insoluble ash figures gives a measure of the straw variation from compost to compost. As mentioned already, most of the soluble ash is derived from the activators added so that the variation in the proportion of activators present is perhaps higher than would be expected (co-efficient of variation is 5·9% when the acid insoluble ash variation is removed). This is not due to errors in the amount of activators added, but more probably to differences in the weight of straw in each compost stack. The amount of straw used was based on the straw bale which varies somewhat in weight and since only two and a half bales were used in each compost this would account for part of the variation found.

**2. Core Sampling in Mushroom Beds**

In Experiment 2 (See M.R.A. Report 1946-1948) 12 different composts were placed, after composting, into 36 beds and a week later 7 or 8 core samples were taken from each bed of 20 square feet with a sampler of $1\frac{1}{4}$ inches diameter. The cores from each bed were combined giving 36 samples, 3 from each compost. After drying and grinding, the samples were analysed for total ash and calcium. These determinations were only done singly so that the estimate includes analytical errors as well as sampling errors, but the latter probably preponderate. Since the furnace used for ashing at this time had no pyrometer the temperature of ashing may have varied between each batch of determinations making the analytical error higher than the 2·3 per cent. obtained above. (Table 14.) It is thus reasonable to assume that the estimate of error determined from the total ash determinations is somewhat high and that the calcium figures give a good estimate of the sampling errors i.e. 5 to 6 per cent. of the mean value (Table 15). The normal practice now is to take six cores for every ten square feet of bed area instead of four so that errors are likely to be within 5%.

**Table 15—Core Sampling Errors**

| | Total ash | Calcium (Ca) |
|---|---|---|
| Mean value (% of dry matter) .... .... | 31·7 | 3·02 |
| Standard error .... .... .... .... | 2·8 | 0·16 |
| Co-efficient of variation .... .... .... | 8·8 | 5·3 |

**3. Sub-sampling for Total Nitrogen**

As stated in the previous report duplicate 20g.-sub-samples are taken from the fresh compost for total nitrogen determinations. The errors involved in this procedure were calculated from the 0·5 N/HCl titrations of the distillate obtained after the Kjeldahl digestion of the 20g.-sub-samples. Table 16 gives the mean errors for each of two composting experiments comprising 24 separate composts, each experiment being sampled at two or three stages. In each experiment the sub-sampling errors decreased from the earlier to the later stages due to the mixing and breaking down of the compost which takes place

**Table 16—Errors in Sub-sampling for Total Nitrogen**

| Sample | Experiment 10 | | | Experiment 11 | |
|---|---|---|---|---|---|
| | 1st. turn | Filling | Empty-ing | Filling | Empty-ing |
| Mean titration .... | 20·5 | 22·0 | 29·5 | 19·8 | 35·7 |
| Standard error .... | 2·04 | 1·50 | 0·89 | 0·98 | 1·10 |
| Standard error of the mean of duplicates .... | 1·44 | 1·06 | 0·63 | 0·69 | 0·78 |
| Co-efficient of variation of the mean .... | 7·0 | 4·8 | 2·1 | 3·5 | 2·2 |

during the course of composting and cropping. The error involved by taking the mean of duplicate determinations was quite considerable at the first turn but no solution to this problem has yet been found since taking a larger sub-sample, or a greater number of sub-samples, would make the method too unwieldy.

**Conclusions**

The largest variations found were those between replicate compost stacks. Part of this variation appears to be due to variations in the composition of the straw and part to variations in the weights of straw bales. Some improvement might be attained by weighing the bales. It also seems desirable to reduce the errors of sampling at the first turn and also of sub-sampling for total nitrogen from the samples taken at the first turn. Alternative methods of sampling in these cases are being considered.

Although the accuracy of the present sampling methods is not very high, the deductions made in this and the previous report from the analytical results are not invalidated by large sampling errors since internal tests for statistical significance have been applied which are independent of the accuracy of sampling or analysis. Greater accuracy would, however, enable more information to be obtained from the results.

## RESULTS

**Losses of Dry Matter During Composting**

Dry matter losses during composting have been calculated for Experiment 9 by the method given in the M.R.A. Report 1946-1948, both from total ash and acid insoluble ash determinations, on samples taken at the first turn and at filling. In this experiment there was some discrepancy between the two methods of calculation, the total ash giving losses averaging 7% higher than the acid insoluble ash.

Table 17 gives the mean values and the standard errors for the different composting treatments. Nitrogen and calcium levels by themselves have no effect on dry matter losses. Differences in the phosphorus treatments are just significant. Differences between east and west stack blocks are also just significant possibly due to the slightly higher temperatures in the composts in the west stack block during composting.

**Table 17—Experiment 9. Dry Matter Losses During Composting**
(1st turn to filling)

| Treatment | Number of Stacks | Mean dry matter loss as % of dry matter at 1st turn | Standard error of the mean | Yield oz./sq. ft |
|---|---|---|---|---|
| Phosphorous omitted | 8 | 34 | | 8·0 |
| Added at start .... | 8 | 39 | 1·6 | 5·65 |
| Added at finish .... | 8 | 37 | | 13·3 |
| Nitrogen 3 .... | 12 | 36·5 | 1·3 | 9·7 |
| Nitrogen 4 .... | 12 | 37 | | 8·3 |
| Calcium 1 .... | 12 | 36 | 1·3 | 8·6 |
| Calcium 2 .... | 12 | 37 | | 9·4 |
| East stack block .... | 12 | 35 | 1·3 | 8·6 |
| West stack block .... | 12 | 38 | | 9·4 |
| $N_3 \times Ca_1$ .... | 6 | 38 | | 10·2 |
| $N_3 \times Ca_2$ .... | 6 | 35 | 1·8 | 9·2 |
| $N_4 \times Ca_1$ .... | 6 | 34 | | 7·0 |
| $N_4 \times Ca_2$ .... | 6 | 39·5 | | 9·7 |

**Table 18—Experiment 9. Composting Dry Matter Losses, Composting Temperatures and Yields**

| Compost treatment | Stack block | Dry matter loss per cent. | Yield oz./sq. ft. | Mean max. temp. during composting °C. |
|---|---|---|---|---|
| $N_3Ca_1$ .... | East | 35 | 8·8 | 64 |
| $N_3Ca_1$ .... | West | 41 | 11·5 | 65 |
| $N_3Ca_2$ .... | East | 33 | 8·5 | 63 |
| $N_3Ca_2$ .... | West | 37 | 9·8 | 66 |
| $N_4Ca_1$ .... | East | 32 | 5·8 | 63 |
| $N_4Ca_1$ .... | West | 37 | 8·3 | 66 |
| $N_4Ca_2$ .... | East | 40 | 11·2 | 65 |
| $N_4Ca_2$ .... | West | 39 | 8·3 | 64 |

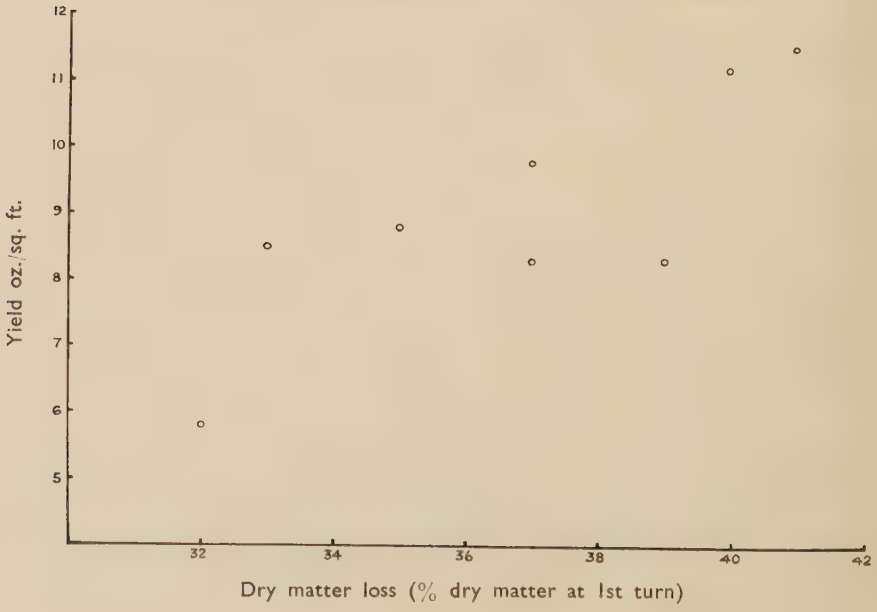
There is also a significant interaction between nitrogen and calcium levels which is very reminiscent of the mushroom yield results. In order to examine this further the phosphorus treatments which had a big effect on yields, were eliminated by taking the mean values of yields and losses for the appropriate composts, thus averaging out the phos-

phorus effects. There was then a significant positive correlation between yields and dry matter losses. In Table 18 are given the mean dry matter losses and yields of each of the three composts in each stack block, having the same nitrogen and calcium treatments and the eight pairs of figures so obtained are shown graphically in Diagram 1. Since both yields and dry matter losses may have been influenced by temperatures during composting the total correlations between all three variables have been obtained and the appropriate partial correlations calculated from them (Fisher, 1947). These are given in Table 19. Since the dry matter loss—temperature correlation cannot be influenced by the yield the total correlation co-efficient was used in this case.

**Table 19—Experiment 9. Dry Matter Loss—Temperature—Yield Correlations. (from eight sets of values)**

| Variables | Dry matter loss—temperature | Temperature—yield | Yield—dry matter loss |
|---|---|---|---|
| Total correlation : co-efficient.... | +0·68 | +0·56 | +0·88 |
| Partial correlation : co-efficient.... | — | —0·11 | +0·83 |
| P corresponding to : correlation co-efficient.... | 0·067 | >> 0·1 | 0·02 |

**DIAGRAM 1. EXPERIMENT 9**
**Yield and dry matter lost during composting**



Similar, but not so convincing, results were obtained in Experiment 10, although here only eight composts (all those containing the blood meal M.R.A. activator) were sampled at the first turn. Again, the losses during composting were calculated both from total ash and acid insoluble ash determinations and the mean value together with corresponding temperatures during composting and the corresponding yields are given in Table 20.

Total and partial correlation co-efficients were again calculated and the results from the two experiments combined by transforming r values to z values (Fisher, 1947) and comparing the mean z values with their respective standard errors. These results are collected together in Table 21 where the probabilities corresponding to each correlation

**Table 20—Experiment 10. Dry Matter Losses, Temperatures and Yields**

| Stack No. | Treatment code | Dry matter loss % dry matter at 1st turn | Yield oz./sq. ft. | Mean max. temperature during composting °C. |
|---|---|---|---|---|
| 2 | $BN_4$ | 30 | 12 | 68 |
| 3 | $BN_3$ | 29 | 18 | 73 |
| 9 | $BN_3$ | 38 | 36 | 67 |
| 11 | $BN_4$ | 30 | 16 | 62 |
| 14 | $BN_3$ | 19 | 23 | 66 |
| 16 | $BN_4$ | 20 | 19 | 61 |
| 21 | $BN_3$ | 38 | 24 | 66 |
| 24 | $BN_4$ | 25 | 16 | 60 |

**Table 21—Experiments 10 and 11. Correlations Between Dry Matter Loss, Yields and Temperatures**

| Variables | Dry matter loss —temperature (total) | | Temperature —yield (partial) | | Yield—dry matter loss (partial) | |
|---|---|---|---|---|---|---|
| Experiment | 9 | 10 | 9 | 10 | 9 | 10 |
| Correlation co-efficients (r) | +0·68 | +0·35 | —0·11 | —0·02 | +0·83 | +0·43 |
| z values .... | +0·83 | +0·36 | —0·11 | —0·02 | +1·19 | +0·56 |
| variance .... | 0·20 | 0·20 | 0·25 | 0·25 | 0·25 | 0·25 |
| weighted mean z values .... | +0·60 | | —0·06 | | +0·88 | |
| Standard error of the mean z values .... | 0·32 | | 0·35 | | 0·35 | |
| P .... .... | 0·06 | | 0·86 | | 0·01 | |

are also given. The significance of the yield—dry matter loss correlation was somewhat improved by this combination of the results for the two experiments, but the dry matter loss—temperature correlation was still not quite significant at the 5% level.

These results show that in these experiments temperatures during composting had no significant effect upon yields, and a somewhat doubtful effect upon dry matter losses although high yields were quite definitely associated with high dry matter losses. The figures given in Table 17 which have already been discussed, indicate that the main factor causing the variation in the rate of composting and hence in the yields was the nitrogen—calcium ratio. Composting temperatures may also be involved in these variations.

**Dry Matter Losses During Cropping**

Only some of the beds in Experiments 9 and 10 were sampled and analysed after the finish of the experiments and only a few of the sampled beds in Experiment 10 corresponded with the composts for which dry matter losses during composting were available. However, for the two experiments twelve sets of figures were available for examining correlations between dry matter losses during composting, dry matter losses during cropping (mean of three beds from each compost) and the corresponding mean yields. These figures are set out in Table 22, and dry matter losses plotted in Diagram 2.

**DIAGRAM 2**

**Effect of dry matter losses during composting upon dry matter losses during cropping**

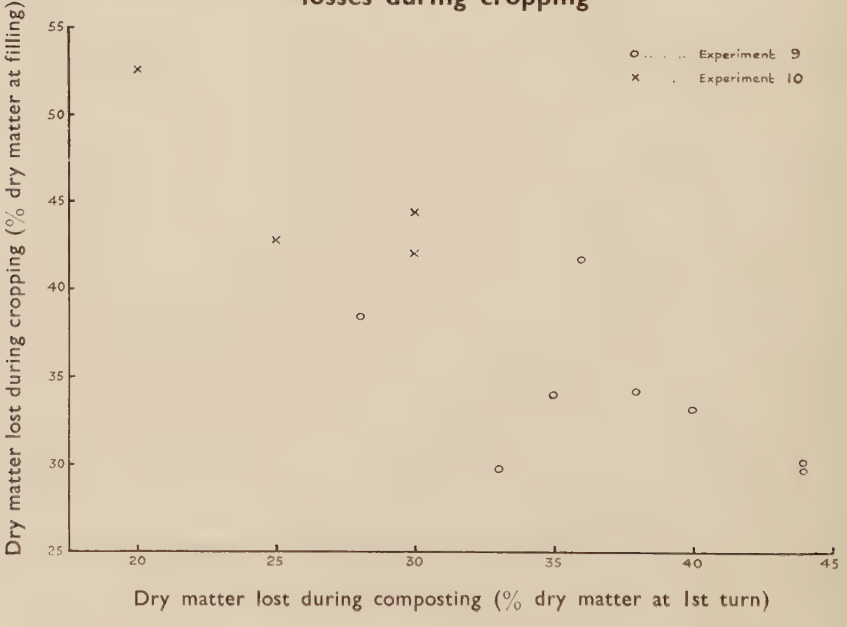


**Table 22—Experiments 9 and 10. Yields and Dry Matter Losses**

| Experiment | Dry matter loss | | Yield oz./sq. ft. mean of three beds |
|---|---|---|---|
| | Composting. % of dry matter at 1st turn | Cropping. % of dry matter at filling, mean of three beds | |
| 9 | 35 | 34·0 | 13 |
| 9 | 38 | 34·3 | 14 |
| 9 | 33 | 29·7 | 8 |
| 9 | 44 | 29·9 | 9 |
| 9 | 28 | 38·5 | 7 |
| 9 | 36 | 41·7 | 14 |
| 9 | 44 | 30·1 | 25 |
| 9 | 40 | 33·1 | 16 |
| 10 | 30 | 42·1 | 12 |
| 10 | 30 | 44·5 | 16 |
| 10 | 20 | 52·7 | 19 |
| 10 | 25 | 42·8 | 16 |

**Table 23 —Experiments 9 and 10. Yield—Dry Matter Loss Correlations**

| Variables | Composting loss —cropping loss | Cropping loss —yield | Yield —composting loss |
|---|---|---|---|
| Total correlation co-efficients .... | —0·839 | +0·222 | +0·058 |
| Partial correlation co-efficients .... | — | +0·499 | +0·460 |
| P .... .... .... | 0·01 | 0·12 | 0·15 |

Total correlations between pairs of these three variables in turn are given in Table 23, together with the corresponding partial correlations where they are relevant. The correlation between yield and loss of dry matter during composting is not significant although a significant correlation was previously obtained for these two experiments. This is due to the fact that the previous correlation was derived from figures relating to 32 separate composts whereas only 12 composts are represented here, so that the errors are much larger. The correlation between yield and dry matter loss during dropping is not significant although it is greatly improved by removal of the effect of losses during composting. The highly significant negative correlation between composting losses and cropping losses suggests that the lower losses during composting leave more of the readily available food material in the compost to be attacked more easily by the mushroom mycelium and (or) other

organisms in the compost. The composts considered here were not peak heated.

Dry matter losses during cropping in Experiments 3, 5, 9 and 10 were collected together and plotted against yields from corresponding composts, the mean losses and yields from the three beds from each separate compost being used for this purpose (Table 24). The hide meal composts which are discussed later were obviously anomalous and were omitted from this series of figures. The scatter diagram so obtained (Diagram 3) suggested a relationship between yield and dry matter loss and, in fact, the two sets of variables gave a correlation co-efficient of +0·414 (n=33 P=0·013) which is highly significant. The improvement in the correlation co-efficient shown in Table 23 when the effect of dry matter losses during composting was eliminated from the correlation between yield and losses during cropping for the limited number of composts for which data was available, suggests that a reason for the scatter shown in Diagram 3 is the effect of composting losses on cropping

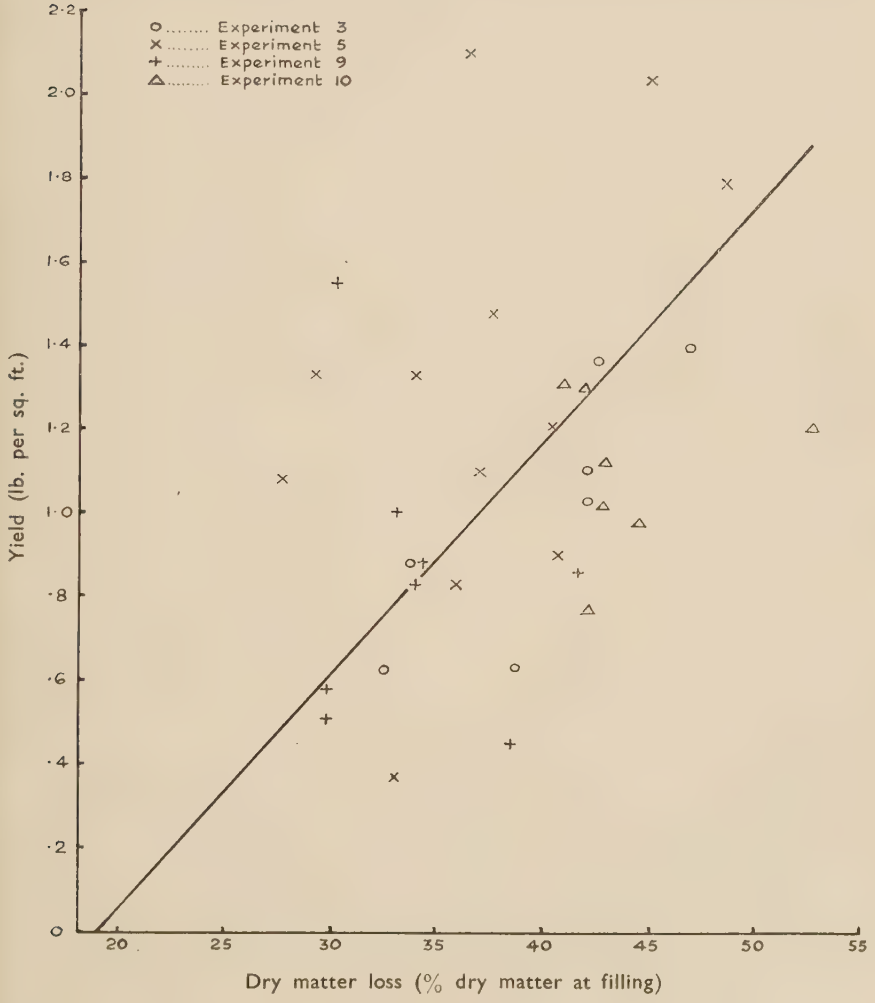
**Table 24 —Dry Matter Loss During Cropping and Yields. Experiments 3, 5, 9 and 10**

| Dry matter loss (per cent. dry matter at filling) | Yield lb./sq. ft. | Dry matter loss (per cent. dry matter at filling) | Yield lb./sq. ft. |
|---|---|---|---|
| **Experiment 3** | | **Experiment 9** | |
| 32·5 | 0·61 | 34·0 | 0·83 |
| 42·6 | 1·37 | 34·3 | 0·87 |
| 33·4 | 0·88 | 29·7 | 0·51 |
| 38·7 | 0·63 | 29·9 | 0·58 |
| 47·0 | 1·40 | 38·5 | 0·45 |
| 42·1 | 1·11 | 41·7 | 0·86 |
| 42·1 | 1·03 | 30·1 | 1·55 |
| | | 33·1 | 1·00 |
| **Experiment 5** | | 27·9 | nil |
| 37.0 | 1·10 | | |
| 33·0 | 0·37 | **Experiment 10** | |
| 27·7 | 1·08 | 42·1 | 0·77 |
| 29·1 | 1·33 | 44·5 | 0·98 |
| 34·0 | 1·36 | 52·7 | 1·21 |
| 36·0 | 0·83 | 42·8 | 1·02 |
| 48·6 | 1·79 | 41·0 | 1·31 |
| 40·5 | 1·21 | 43·0 | 1·12 |
| 36·5 | 2·10 | 42·0 | 1·30 |
| 40·4 | 0·90 | | |
| 45·0 | 2·04 | | |
| 37·7 | 1·48 | | |

losses, previously established (Diagram 2). The mean line shown in the figure was fitted by Bartlett's method (Bartlett, 1949) and its slope indicates an average dry matter loss of 18% for each pound per square foot crop. In addition the intercept on the horizontal axis shows an average loss, independent of the mushroom crop, of 19%. This extraneous loss suggests that other organisms apart from the mushroom attack the compost to a considerable extent, and thus the dry matter loss during cropping may be divided in two parts – that due to the activities of the mushroom and that due to other micro-organisms. Factors producing

**DIAGRAM 3**

**Relation between yield and dry matter lost during cropping**



the scattering of the points in the figure may operate by altering the slope of the line or its intercept on the horizontal axis. In other words since composting loss is one of these factors it may either affect the activity of the compost microflora or the amount of mycelial activity of the mushroom for a given yield of mushrooms. It seems probable that the higher the dry matter loss during composting the lower will be the activity of the compost microflora during cropping thus leading to less competition for the available food, and a higher mushroom crop. If the higher composting loss led to a lower consumption of compost by the mushroom mycelium itself a lower crop would be expected to result unless the ratio between yield and loss during cropping due to mushroom mycelium increased, which seems improbable. A higher composting loss has been shown, in fact, to be followed by a higher crop in Experiment 9 and possibly in Experiment 10 also, thus leading to the conclusion that the lower losses during cropping, consequent upon high losses during composting, are due to the reduction in the growth of competing organisms and not to less active growth of mushroom mycelium.

The unusual behaviour of the hide meal composts has already been mentioned. At the end of cropping, beds of these composts had sunk very much less than the rest of the beds. These composts were initially very dark in colour and even after cropping they retained their dark colour and also they appeared little decomposed although normal composts are dusty and of a light brown colour after cropping. Table 25 shows a comparison of the dry matter losses during cropping from blood meal composts, beet tailing composts and hide meal composts in Experiment 10. The hide meal composts sustained less than half of the loss of dry matter shown by the remainder of the composts although they gave yields of the same order. Unfortunately, composting losses were not determined, but the acid insoluble ash figures at filling do not suggest any excessive decomposition during composting which might have reduced cropping losses. It is interesting to note that the hide meal composts yielded about one pound of mushrooms per square foot with a

**Table 25 —Experiment 10. Effect of Nitrogen Source on Dry Matter Loss**

| Stack No. | Description | Number of beds analysed | Dry matter loss % of dry matter at filling | Standard error of the mean |
|---|---|---|---|---|
| 2 | Blood meal | 3 | 42·1 | |
| 11 | ,, ,, | 3 | 44·5 | 1·2 |
| 16 | ,, ,, | 3 | 52·7 | |
| 24 | ,, ,, | 3 | 42·8 | |
| various | ,, ,, | 1 bed from each of | 42·0 | 3·3 |
| various | Hide meal | 4 replicate stacks | 16·7 | |
| 13 | ,, ,, | | 17·4 | |
| 10 | Beet tailings | 2 beds from each | 41·0 | 2·4 |
| 15 | ,, ,, | stack | 43.0 | |

dry matter loss of 17% per lb. of mushrooms per square foot which is about the same as the figure of 18% per lb. obtained from the slope of the mean which gives the loss of dry matter due to mushroom growth alone. This suggests the interesting possibility that the small dry matter losses in the hide meal composts were due to reduced activity by other micro-organisms.

Previous work by both Waksman and Nissen (1932) and Stoller (1936) support the idea that the compost microflora is more active than mushroom in consuming the compost substance, although neither worker was operating under commercial mushroom growing conditions. Waksman found dry matter losses during mycelial growth in sterilised compost in bottles to be less than twenty per cent. in 7 months at 27° C. and Stoller found that carbon dioxide production by unspawned compost was similar to that from spawned composts.

**Dry Matter Losses During Composting and Peak Heating**

Acid insoluble ash figures alone were used to calculate the dry matter losses during composting in Experiment 11. The 24 composts were composted for varying periods which are shown in Table 26 together with the mean dry matter losses. There are highly significant losses between third and fourth and between fourth and fifth weeks but there is no significant loss between fifth and sixth weeks. The rate of dry matter loss, also shown in the table, is the difference between the losses for two consecutive weeks ; except for the third week where the rate of loss was obtained by subtracting the loss at the third week from zero (which is the loss at the first week when the reference samples were taken) and dividing by two. There is a decided trend towards lower rates of dry matter loss as composting proceeds. This is as would be expected since the more easily available material would be used up first and decomposition of the resistant material takes place more slowly.

**Table 26—Experiment 11. Dry Matter Losses From the 1st Turn to Filling**

| Composting period (weeks) | 3 | 4 | 5 | 6 |
|---|---|---|---|---|
| Dry matter loss % (mean of six composts) .... | 18·3 | 26·0 | 34·0 | 36·5 |
| Standard error of the mean .... | 1·9 | 1·9 | 1·9 | 1·9 |
| Dry matter loss per week .... | 9·1 | 7·7 | 8·0 | 2·5 |

Five weeks after spawning, twelve beds in this experiment were core sampled for another purpose, the position of sampling being arranged so that the bottom third of the core had no mushroom mycelium in it. These bottom sections were combined according to the compost treatment, giving a sample from each of four composts which had been composted for different periods. In this cropping experiment a peak heat temperature had been obtained in the house and it is reasonable to assume that the major part of the fermentation took place during this peak heating so that dry matter losses from the time of filling,

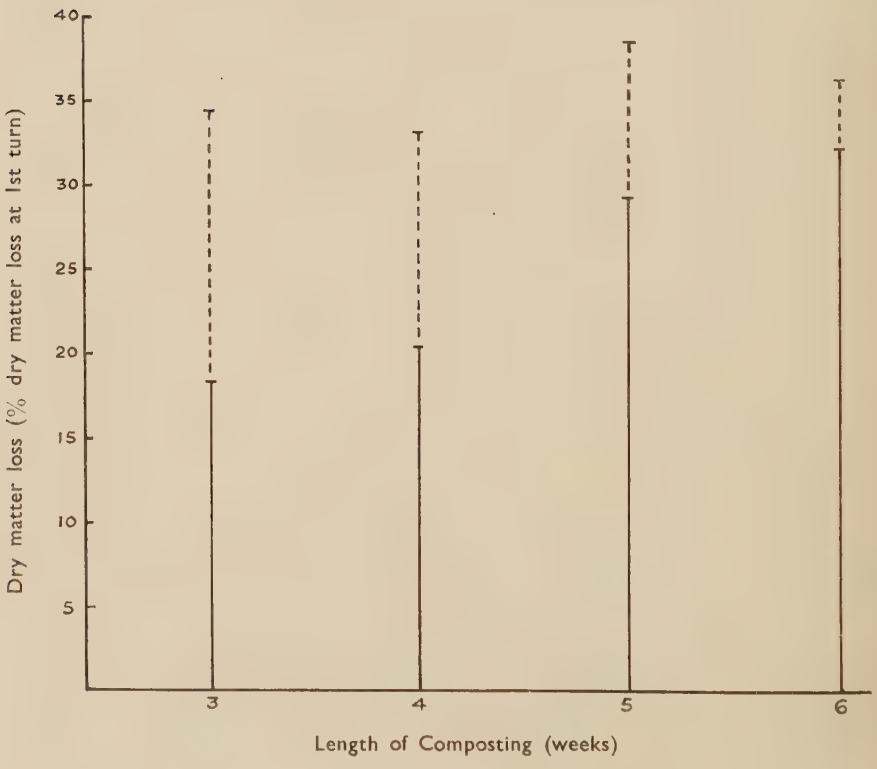
**Table 27—Experiment 11. Dry Matter Losses During Peak Heating**

| Composting period (weeks) | | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Dry matter loss during composting .... | per cent. of dry matter at 1st turn | 18·3 | 20·5 | 29·2 | 32·2 |
| Dry matter loss during peak heating.... | | 16·1 | 12·7 | 9·3 | 4·1 |
| Total .... .... .... | | 34·4 | 33·2 | 38·5 | 36·3 |
| Final yield oz./sq. ft. | | 26 | 37 | 41 | 33 |

**DIAGRAM 4**

**Composting and peak heating dry matter losses**

Full line represents loss during composting
Dotted line represents loss during peak heating



calculated from the acid insoluble ash in these samples, gave a good indication of the degree of fermentation during peak heating. It will be seen from Table 27 and Diagram 4 that these losses, which are calculated as a percentage of the dry matter at the 1st turn, diminished as the dry matter losses during composting increased and the correlation between the two is not quite significant at the 5% level when z values are used instead of r values, z values being more appropriated in this case since the number of results is so small. (z = —1·91, standard error = 1·00, P = ·056). The four samples were all taken from middle beds so that air temperatures were uniform although bed temperatures may have varied owing to uneven rates of fermentation. On adding the loss during peak heating to the loss during composting the total losses from the first turn to the fifth week after peak heating are remarkably

**Table 28—Experiment 9. Nitrogen Losses During Composting**
Total nitrogen at stacking $N_3$—2·5% ; $N_4$—3·3%

| Phosphorous treatment | | Superphosphate omitted | | Superphosphate added at start | | Superphosphate added at finish | |
|---|---|---|---|---|---|---|---|
| Nitrogen level | Calcium level | Nitrogen loss % | Temperature °C | Nitrogen loss % | Temperature °C | Nitrogen loss % | Temperature °C |
| $N_3$ | $Ca_1$ | 0·1 | 63 | nil | 62 | 0·2 | 66 |
| | | 0·5 | 63 | 0·9 | 66 | 0·3 | 67 |
| | $Ca_2$ | 0·3 | 64 | nil | 61 | 0·2 | 65 |
| | | nil | 64 | 0·6 | 69 | 0·6 | 64 |
| $N_4$ | $Ca_1$ | 0·6 | 65 | 0·8 | 63 | 0·3 | 61 |
| | | 1·1 | 66 | 1·1 | 66 | 1·1 | 66 |
| | $Ca_2$ | 1·0 | 64 | 0·9 | 65 | 1·4 | 67 |
| | | 0·9 | 65 | 1·4 | 67 | 1·1 | 61 |

**Table 29—Experiment 9. Nitrogen Loss, Temperature, Nitrogen Level Correlations**

| Variables | Nitrogen loss—temperature | Nitrogel level—temperature | Nitrogen loss—nitrogen level |
|---|---|---|---|
| Total correlation co-efficients | +0·429 | +0·040 | +0·756 |
| Partial correlation co-efficients | +0·611 | — | +0·819 |
| P .... .... | < ·01 | >> ·1 | < ·01 |

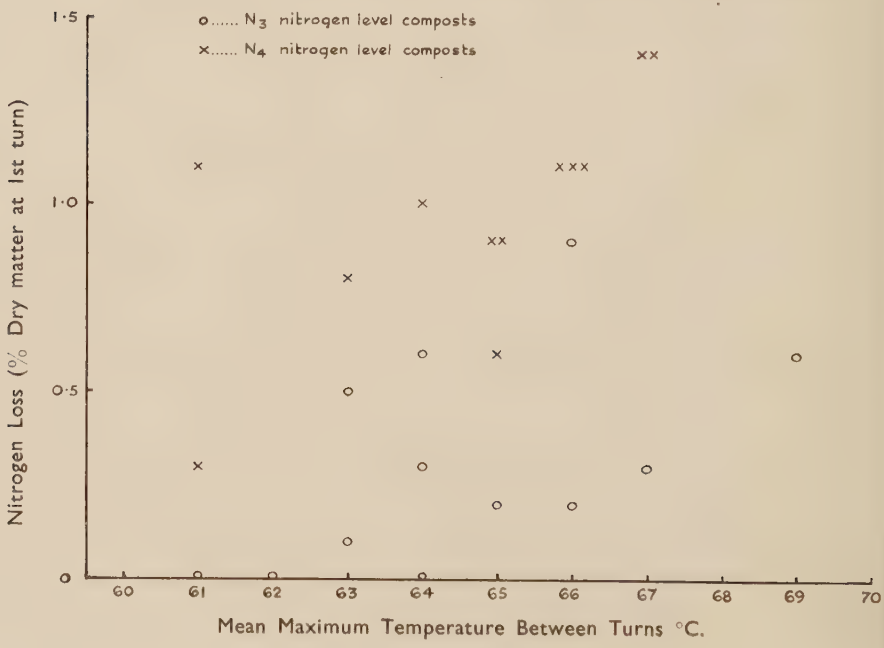
uniform considering the different periods of composting involved. Thus peak heating had a distinct levelling up effect on the loss of dry matter and this may be one reason for the more consistent crops obtained in this experiment.

**Nitrogen Losses During Composting**

In the M.R.A. Report 1946-1948, it was shown that losses of total nitrogen during composting depended upon the level of nitrogen present at stacking. This has now been demonstrated more rigorously in Experiment 9 where two levels of nitrogen were used. Since mean temperatures during composting also varied considerably from stack to stack and appeared to have an effect on nitrogen losses, correlation co-efficients have been calculated for pairs of the three variables in turn. The figures upon which the co-efficients are based are given in Table 28, and the total and, where applicable, the partial correlation co-efficients in Table 29. Nitrogen at stacking was estimated from the nitrogen contents of the constituents, and dry matter losses were used to calculate absolute nitrogen losses from the nitrogen content at filling.

The probability figures in the bottom line of Table 29 confirm the previous observation of the effect of nitrogen level on nitrogen loss and show that the temperature also has a marked effect on nitrogen losses. Nitrogen losses plotted against temperatures in Diagram 5, show that in the region of 70° C. (mean of maximum stack temperatures between

**DIAGRAM 5.**
**Composting temperature and nitrogen losses. Experiment 9**



turns) the losses are high, whereas below 60°C. losses are almost neglibible. Temperatures were not affected by the level of nitrogen in this experiment although in Experiment 3 (M.R.A. Report 1946-1948) where lower nitrogen levels were used, composting temperatures increased with the nitrogen level.

**Nitrogen Loss During Cropping**

The dependence of the loss of nitrogen during cropping upon the amount of nitrogen present in the compost which was observed in Experiment 5 (M.R.A. Report 1946-1948) has been confirmed. Taking the analyses available for Experiments 3, 5, 8 and 9 together (see Table 30) giving 29 pairs of figures corresponding to 29 separate composts and 87 beds, the correlation co-efficient between nitrogen loss and nitrogen originally present, was + 0·634 (n = 27 ; P + 0·01). Six composts (the only ones analysed sufficiently for the nitrogen loss calculations to be made) from Experiment 10 (See Table 30) taken separ-

**Table 30—Experiments 3, 5, 8, 9 and 10. Nitrogen Losses During Cropping**

| Original nitrogen (per cent. dry matter at filling) | Nitrogen loss (per cent. dry matter at filling. Mean of three beds from each compost) | Original nitrogen (per cent. dry matter at filling) | Nitrogen loss (per cent. dry matter at filling. Mean of three beds from each compost) |
|---|---|---|---|
| **Experiment 3** | | **Experiment 8** | |
| 1.70 | 0·14 | 3·02 | 0·87 |
| 2·39 | 0·27 | 2·87 | 0·55 |
| 2·39 | 0·62 | | |
| 2·84 | 1·24 | | |
| 3·12 | 0·75 | **Experiment 9** | |
| 2·84 | 1·00 | 3·46 | 1·27 |
| 2·58 | 0·98 | 3·62 | 1·45 |
| | | 3·50 | 1·28 |
| **Experiment 5** | | 3·41 | 1·28 |
| 2·32 | 0·87 | 4·20 | 2·02 |
| 2·53 | 1·02 | 3·49 | 1·56 |
| 2·25 | 0·77 | 3·42 | 1·12 |
| 2·17 | 0·55 | 3·62 | 1·71 |
| 2·36 | 0·75 | | |
| 2·39 | 0·77 | **Experiment 10** | |
| 2·56 | 1·23 | 3·19 | 1·22 |
| 2·79 | 1·08 | 4·02 | 1·94 |
| 2·80 | 1·21 | 2·58 | 0·84 |
| 2·79 | 1·51 | 3·51 | 1·80 |
| 2·81 | 1·40 | 2·80 | 1·33 |
| 3·02 | 1·25 | 2·69 | 1·36 |

ately from the other figures, gave a correlation co-efficient of 0·851 ($n = 4$ $P < 0·05$)

Further analyses of soil after cropping confirmed the small increase in nitrogen content already noted in the M.R.A. Report 1946-1948 (see Table 31). The failure to account for a large proportion of the lost nitrogen is therefore corroborated and the previous suggestion that denitrification takes place extensively in the cropping beds remains the only likely explanation. In Experiment 9 two or three beds failed to crop and showed no evidence that spawn growth had occurred, yet nitrogen losses from these were of the same order as from the other beds (Table 32). This shows that mushroom mycelium itself does not bring about denitrification nor is it necessary for the mycelium to break

**Table 31—Nitrogen in Casing Soil**

| Bed number | Gain of nitrogen lb./10 sq. ft. |
|---|---|
| 2 | ·016 |
| 4 | ·029 |
| 5 | ·022 |
| 11 | ·019 |
| 14 | ·022 |
| 25 | ·020 |
| 26 | ·016 |
| 34 | ·026 |
| 42 | ·018 |
| 45 | ·026 |
| 49 | ·022 |
| 67 | ·012 |
| Mean | 0·021 |

**Table 32—Nitrogen Losses from Typical Beds in Experiment 9**

| Nitrogen loss % dry matter at filling | Yield lb./sq. ft. | Remarks |
|---|---|---|
| 1·52 | 1·16 | |
| 1·40 | 0·13 | |
| 2·03 | 1·13 | |
| 1·32 | 0·49 | |
| 1·22 | 2·18 | |
| 1·57 | nil | Good spawn run |
| 1·46 | 0·01 | Poor spawn run |
| 1·42 | nil | No spawn run |
| 1·48 | nil | No spawn run |

down the complex nitrogen compounds in the compost before denitrification can take place. The evidence points to direct bacterial action upon the compost proteins, possibly in competition with the mushroom spawn.

The low losses of dry matter from the hide meal composts in Experiment 10 during cropping would lead one to expect low losses of nitrogen also if bacterial action were concerned in both of these processes. The results show that this is indeed the case and the reduction in the losses is of the same order as the reduction in dry matter losses. Table 33 summarises these results and shows that the difference in nitrogen losses is not due to differences in original nitrogen percentages since the mean figures are almost identical.

**Table 33—Experiment 10. Hide Meal Nitrogen Losses**
(Results expressed as per cent. of dry matter at filling)

| | Number of beds analysed | Mean dry matter loss | Mean original nitrogen | Mean nitrogen loss | Standard error of the mean (nitrogen losses only) |
|---|---|---|---|---|---|
| Hide meal | 8 | 17·2 | 3·10 | 0·56 | 0·14 |
| Blood meal .... | 16 | 44·6 | 3·29 | 1·40 | 0·14 |

**Calcium Oxalate in Spent Compost**

Determinations have been made of calcium oxalate in 36 beds from Experiment 5 and 29 beds from Experiment 9. The amounts varied erratically from bed to bed with no apparent relation to yield nor to any compost treatment. Experiments are in progress to test the suggestion made in the previous report that oxalate is reassimilated by the mushroom after it is first formed. The figures so far obtained show that calcium oxalate is formed rapidly at the start of spawn growth but analyses later in the cropping period have not yet been done. These figures will be reported in full at a later date.

**Selective Toxicity of Some Dyes**

In view of the evidence which has accumulated that bacterial action in mushroom composts is very considerable even after good composting, and also that a reduction in this bacterial activity by good composting results in increased yields of mushrooms, a search has been commenced for substances which will inhibit the growth of these bacteria but will not affect the mushroom.

Three substances, rose bengal, potassium thiocyanate and methylene blue which have a known specific action, were investigated. Rose bengal (Dawson, 1949) and potassium thiocyanate are used in mycological technique for preventing the growth of bacteria in fungus colonies, and methylene blue has been used to prevent nitrification without affecting the oxidation of organic matter, in biochemical oxygen demand determinations upon sewage (Abbott, 1948).

Well composted horse manure was allowed to dry out to a moisture content of 60% and was then rubbed through a $\frac{1}{4}''$ sieve, rejecting straw that would not pass through. After removing samples for moisture and total nitrogen determinations it was divided into eight 200 g.—lots and 10 ml. of water or solution added to each according to the following scheme and well mixed in.

| | Concentrations of solution used. (% $\frac{w}{v}$) | Parts per million of compost |
|---|---|---|
| Potassium thiocyanate .... | 1·0 | 500 |
| | 5·0 | 2500 |
| Rose bengal .... .... .... | 0·02 | 10 |
| | 0·2 | 100 |
| Methylene blue .... .... | 0·005 | 2·5 |
| | 0·05 | 25 |
| | 0·5 | 250 |

Eight 20 g.—portions from each treated 200 g.—lot were then evenly packed into $7'' \times \frac{7}{8}''$ hard glass boiling tubes and plugged with cotton wool. The 64 tubes were incubated in a humid atmosphere for 22 hours at 54° C., to imitate the peak heating process used in normal cultivation, and then four of the eight tubes in each treatment were spawned with 1g. of moist spawn of known moisture and nitrogen content. After replugging with cotton wool all the tubes were incubated at 25° C. in a moist atmosphere and in the case of the spawned tubes the mycelial growth down the tubes was measured at intervals of 2, 4 and 5 weeks. Growth in the controls was somewhat slower in starting than in the other treatments so that the growth from the fourth to the fifth week has been used for comparing the effects of the treatments. Growth during this period was the most consistent between replicates.

Eight weeks after spawning two spawned and two unspawned tubes in each treatment were taken and the compost removed from the tubes, weighed and analysed for moisture and total nitrogen. The difference in dry weight before and after the experiment gave the loss of dry matter and from these figures the loss of nitrogen was also calculated. Table 34 gives the means from duplicate tubes and the treatment means. Nitrogen losses were very small and no significant differences were apparent. Dry matter losses were also low but the three methylene blue treatments all showed significant reductions in dry matter losses compared with the control and significant increases in the rate of linear mycelial growth (Table 35). Rose bengal increased the mycelial growth rate to the same extent as methylene blue but had no effect upon dry matter losses. Potassium thiocyanate was toxic to mushroom mycelium and also had no effect upon dry matter losses. The results give no indication as to whether the increased mycelial extension rate in the dye treatment is connected with any suppression of competition for nutrients which may have occurred.

**Table 34—Test Tube Growth Experiment, Dry Matter and Nitrogen Losses**

| Treatment | Dry matter losses (%) | | | Nitrogen losses (%) | | |
|---|---|---|---|---|---|---|
| | Spawned | Un-spawned | Mean (s.e. 0·8) | Spawned | Un-spawned | Mean (s.e. 0·03) |
| Control .... | 8·4 | 9·6 | 9·0 | 0·13 | 0·22 | 0·18 |
| Potassium thiocyante | | | | | | |
| 500 p.p.m. .... | 9·7 | 8·8 | 9·2 | — | — | — |
| Rose bengal | | | | | | |
| 10 p.p.m. .... | 9·4 | 5·6 | 7·5 | 0·23 | 0·15 | 0·19 |
| 100 p.p.m. .... | 8·6 | 7·5 | 8·0 | 0·13 | 0·22 | 0·18 |
| Methylene blue | | | | | | |
| 2.5 p.p.m.... | 7·1 | 5·2 | 6·2 | 0·15 | 0·20 | 0·18 |
| 25 p.p.m. .... | 4·2 | 3·2 | 3·7 | 0·15 | 0·10 | 0·12 |
| 250 p.p.m. .... | 5·1 | 3·9 | 4·5 | 0·15 | 0·19 | 0·17 |
| Mean .... | 7·5 | 6·3 | | 0·16 | 0·18 | |
| s.e. of mean .... | 0·45 | 0·45 | | 0·02 | 0·02 | |

**Table 35—Effect of Selective Bacteriostatic Substances Upon Mushroom Mycelium Growing in Compost**

| Treatment | Linear growth from 28th—35th day mean of four tubes (mm.) | Significant effects compared with control (standard error of mean = 1·2 mm.) |
|---|---|---|
| Control .... .... .... | 43 | — |
| Potassium thiocyanate | | |
| 500 p.p.m. .... .... | 37 | decrease |
| 2500 p.p.m. .... .... | 20 | decrease |
| Rose bengal .... .... | | |
| 10 p.p.m. .... .... | 50 | increase |
| 100 p.p.m. .... .... | 51 | increase |
| Methylene blue .... | | |
| 2·5 p.p.m. .... .... | 50 | increase |
| 25 p.p.m. .... .... | 49 | increase |
| 250 p.p.m. .... .... | 50 | increase |

Quastel and his co-workers have examined the specific action of various dyestuffs upon enzymes (e.g. Quastel, 1931) and Dion & Lord (1944) have tested the differential toxic effect of dyes upon fungi. These results suggest that some of the known dyestuffs may have a specific toxic effect upon bacteria or fungi. The cheapest of those

already at hand in the laboratory were therefore chosen for further tests. These are given in Table 36 together with their effect upon mycelial growth determined in a similar manner to that given above. Their effect upon dry matter losses was not determined and the growth rate experiment gave very poor agreement between replicates probably owing to uneven drying out of the compost at the top of the tubes during peak heating. The results were, however, sufficient to show whether any marked reduction in the rate of mycelial extension occurred compared with the control.

Methylene blue, aniline blue, malachite green, methyl violet and titan yellow appeared to have little if any effect upon growth rates, even (with the omission of malachite green) at the high concentration of 0·1% of the whole compost. Since malachite green and methyl violet have recognised bacteriostatic properties these results although of a very preliminary character are encouraging.

**Mycelial Growth Rates**

During the experiments outlined above it was noted that the rate of mycelial growth was not uniform but increased with time and the plot of mycelium length against time had a roughly logarithmic form up to five weeks after spawning (Diagram 6 ; Curve A). Further, when the rate of linear growth was plotted against the distance of the newly formed mycelium from the inoculum an approximately straight line was obtained (Diagram 7 ; A). This finding is contrary to the results of Falck (1907), Bateman (1933) and other workers, who obtained linear growth rates in pure cultures of wood rotting fungi. In a later

**Table 36—Effect of Dyes on Mycelial Growth**

0 = no reduction of growth
— = reduction of growth

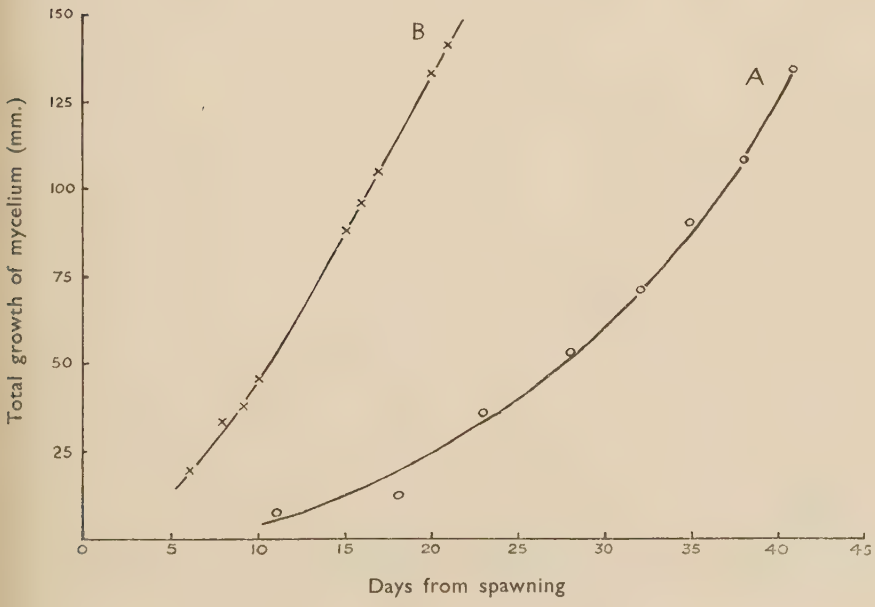
| Dye | Parts per million | Effect | Dye | Parts per million | Effect |
|---|---|---|---|---|---|
| Methylene blue | 100 | 0 | Aniline blue | 100 | 0 |
| | 1,000 | 0 | (water soluble) | 1,000 | 0 |
| Neutral red .... | 100 | — | Malachite green | 10 | 0 |
| | 1,000 | — | | 100 | 0 |
| | | | | 1,000 | — |
| Safranine .... | 10 | 0 | | | |
| | 100 | — | Methyl violet | 10 | 0 |
| | 1,000 | — | | 100 | 0 |
| | | | | 1,000 | 0 |
| Gentian violet | 10 | — | | | |
| | 100 | — | Bismark brown | 100 | — |
| | 1,000 | — | | 1,000 | — |
| Acid fuchsin | 100 | — | Titan yellow | 100 | 0 |
| | 1,000 | — | | 1,000 | 0 |

growth experiment in three long tubes of compost a rapid rate of mycelial growth was quickly established and remained uniform after the tenth day. The maximum rate attained was 9 mm. per day as against a previous maximum of 7·5 mm. per day (Diagram 6 ; Curve B and Diagram 7 ; Curve B). These three tubes were open at both ends but two of them were plugged at both ends with cotton wool and the other sealed at the end opposite to the spawned end. Rates of linear growth in all three were the same when the maximum rate had been reached and this equivalence continued to the end of the tubes showing that the restricted aeration in the tube sealed at one end was of no consequence. When growth had reached 140 mm. the spawn and the compost with mycelium in it was carefully removed from one of the other tubes down to a point 10 mm. short of the tips of the growing hyphae and the now empty part of the tube filled with moist cotton wool. No effect upon the rate of extension was observed although the new mycelium was much less dense in the treated tube for some days after this treatment. The meaning of these results is not clear but further work may give information relating to the mode in which the mycelium derives its nutriment from compost.

## DIAGRAM 6

### Rate of linear growth of mushroom mycelium

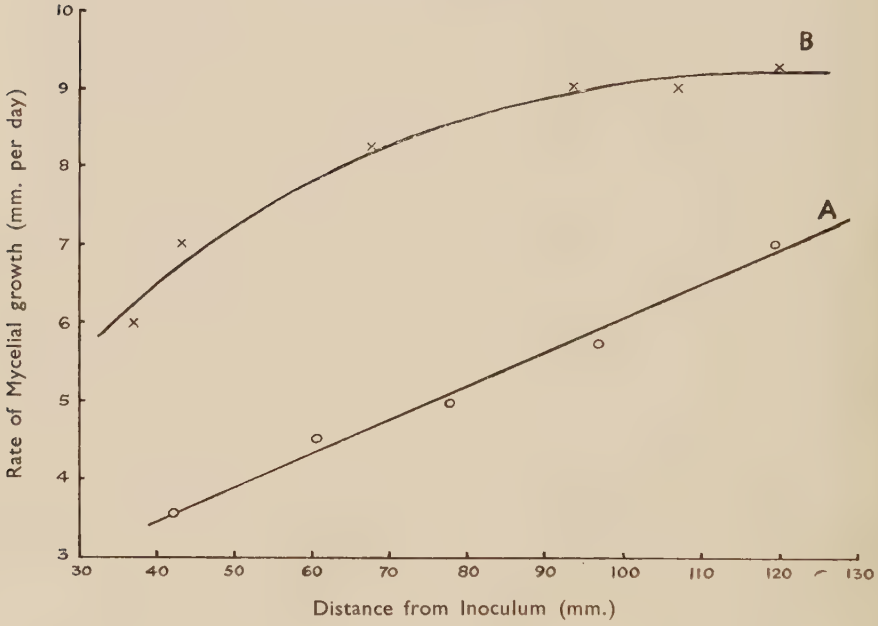
The two curves show rates of growth in tubes of two different samples of horse manure compost



## DIAGRAM 7

**Relation between growth rate and distance from inoculum**

Curves A and B respectively correspond to those labelled similarly in Diagram 6

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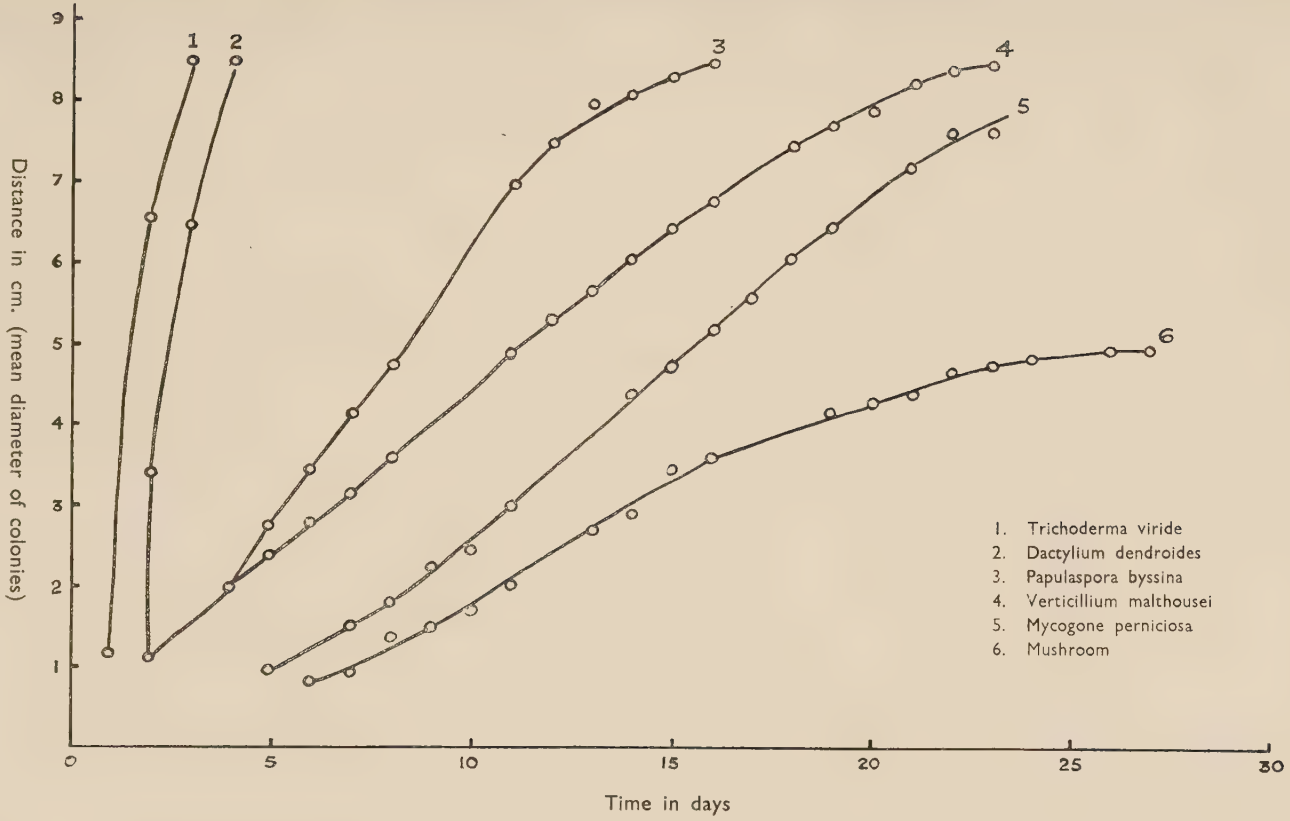
## DIAGRAM 8—GROWTH RATE EXPERIMENT



# MICROBIOLOGY DEPARTMENT
## Miss C. Duncan

During the year observations were made on the occurrence and severity of attack of fungi in mushroom beds, based on samples submitted by growers. Many of these fungi seemed to occur at definite times of the year. What the growers call Vert-de-Gris seemed to appear in the early part of the year to July, whilst *Papulaspora byssina* (Brown plaster mould) flourished over a longer period from April to October, with peak months August and September. *Verticillium* spp. and *Mycogone perniciosa* (Bubble) were more prevalent from June to October, especially during August and September. *Pseudobalsamia microspora* (Truffle), *Scopulariopsis fimicola* (White plaster mould) and bacterial diseases appeared mainly in September and October. Finally, *Sporendonema* sp. (Red Geotrichum) was noted mainly during the period from September to November. Several of the fungi appeared in say, one case only, or twice as in the case of *Oedocephalum fimetarium*, which was recorded in June. In both cases the growers feared that the fungus would damage their crop, and in both cases mushrooms eventually grew through it.

### Fungi identified on Mushroom or Mushroom Beds

**Parasitic on Mushroom**

*Dactylium dendroides*
*Mycogone perniciosa*
*Verticillium malthousei*

**Competitors and Invaders**

*Chaetomium* sp.
*Clitopilus cretatus*
*Coprinus* sp.
*Corticium centrifugum*
*Oedocephalum fimetarium*
*Scopulariopsis fimicola*
*Sporendonema* sp. (Red Geotrichum)
*Papulaspora byssina*
*Peziza vesiculosa*
*Pseudobalsamia microspora*
*Tomentella granulata*
*Trichoderma viride*
Vert-de-gris

**Invaders or Competitors ?**

In order to begin to determine whether certain fungi were actually competitors or harmless invaders and with a view to collecting data for infection experiments certain growth experiments were set up. As the mushroom is a notoriously slow grower in pure culture it was decided that a check on the growth rate of a few of the commoner fungi, found in mushroom beds, and already in pure culture, would be useful. By determining the comparative growth rates, it might then be

possible to decide whether the suspected antagonists or competitors are so dangerous at all stages of mushroom culture, or whether at some stage of growth the mushroom is capable of competing and defeating competitors primarily considered to be dangerous at all stages, irrespective of age or condition of the mushroom bed. Of the fungi selected, so far, five have given definite results. Unfortunately three of these are well established parasites and there is no doubt about their status in a mushroom bed.

**Growth Rate Experiments**

Petri dishes of 8·5 cm. diameter were selected and the base of each dish was marked with 4 intersecting axes termed A, B, C and D. A shallow layer of malt agar was poured into each plate, and at the point of intersection of the 4 axes, various fungi were inoculated. The fungi used were *Verticillium malthousei, Mycogone perniciosa, Dactylium dendroides, Papulaspora byssina, Trichoderma viride,* and the cultivated mushroom. Measurements were taken daily when an appreciable amount of growth had taken place. These were made along the 4 axes and the mean taken. Growth varied with the respective fungi, and the graph has been made from the first measurement at the appropriate number of days after the primary inoculation. Thus *D. dendroides, T. viride* and *P. byssina* had grown an appreciable distance one day after inoculation. *V. malthousei* and *M. perniciosa* came next and the mushroom mycelium took 9 to 10 days before any measurements could be made.

Growth rates varied enormously. Mushroom mycelium grew steadily after 10 or 12 days, but tailed off 24-26 days after inoculation. This may have been due to drying out of the medium. *V. malthousei,* however, covered twice the same area in approximately the same time ; growth was steady from the first and showed no signs of abating. *M. perniciosa* took 23 days to cover the plate, *P. byssina* took 16 days. *D. dendroides* and *T. viride* took 3-4 days only.

The potentialities of *D. dendroides, M. perniciosa* and *V. malthousei* are only too well known, so far as the grower is concerned, but *T. viride* as a commonly occurring fungus is an unknown quantity whose rapid growth could prove detrimental to the mushroom.

Dyed cellulose film (S. Burrows, 1949,) plus nutrient material was also used as a medium. Fungi would grow through this medium as in the natural condition in the soil, rather than on the surface of an agar plate. Density of growth appears to be quite as important as linear growth. Drying out of the medium was also lessened by the addition of nutrients in liquid form. Mushroom has been grown quite successfully in this medium, inoculated at one end of a double-ended tube. When the growth rate has been established the possible antagonist will be introduced into the other end of the tube.

**Infection Experiments**

In order to investigate controls of various diseases of mushrooms, infection experiments were set up. Practical difficulties necessitated the use of an isolation cell, and one was devised so that these experiments could be kept in the test houses.

Litre beakers were two-thirds filled with compost and the whole incubated at 55° C. (131° F.) for 36-48 hours simulating the grower's

peak heat. When the beakers had cooled, they were spawned to a depth of about an inch. As the compost usually dried out a little the top dry section was raised, the moist spawn was packed down on the moister compost below and the dry compost was replaced on top. The beakers were then placed in the test houses. After about 14 days, when the spawn run was well established, the beakers were cased. Until the appearance of the first pinhead the beakers were kept uncovered. When a pinhead did appear the appropriate beaker was placed on a tray of sand treated with mercuric chloride and dilute glycerol to maintain a suitable humidity, and covered with a bell jar the neck of which was blocked with a cotton-wool plug. Sand cultures of *V. malthousei* were used to inoculate the soil. The fungus was cultured on sterile autoclaved sand bound together with a layer of malt agar. When a pinhead appeared the inoculum was placed on the soil beside it. This procedure was adopted several times, with a control in each case, but the mushroom always outgrew *V. malthousei*. It is suggested that the humidity and temperature inside the bell jars were not high enough or maintained long enough for *V. malthousei* to infect the mushroom. Attempts are now being made to control these conditions.

**Pseudobalsamia microspora,** Diehl & Lambert

Samples of soil were tested for the presence of *P. microspora*, better known to growers as truffle. The technique devised by H. H. Glasscock and W. M. Ware (1940) was employed. Twenty boiling tubes were two-thirds filled with moistened pure culture spawn and cased with about ½ in. of six different moistened soils, A, B, C, D, E and F, there being four boiling tubes to each soil. The tubes were then plugged with cotton-wool and incubated at 29° C. (83° F.), the suggested optimum temperature.

From the six sets of tubes set up, truffle fruiting bodies were found in four. Of the remaining tubes cased by the infected soils, half were contaminated by other fungi, the other half were clear.

The tubes containing the truffle bodies appeared to be slightly moister than the others. pH measurements of all tubes were taken. Unfortunately no check was made before the experiment was set up, as primarily only the technique was being tested, however the clean tubes were taken as controls. Contaminated tubes were also measured to compare any change in pH that might be attributed to the presence of invading fungi other than truffle.

The average pH of the clean tubes was 6·3
The average pH of the contaminated tubes was 6·3
The average pH of the tubes containing truffle was 6·6

It would appear then, that the pH of the tubes containing truffle bodies, was higher than either that of the contaminated tubes, or the clean tubes. Whether this is due to the presence of the truffle, or whether the pH change took place first and was advantageous to the truffle is not known.

A further experiment was started based on the two main points noted in the former experiment :—(1) The moist appearance of the spawn in the truffle infected tubes. (2) The change in pH noted,

The four soils A C, D and E known to have produced truffle in the former experiment were used. The other two which gave negative results were discarded. The fact that no truffle had been obtained did not necessarily mean that these soils were clean, but the appearance of truffle in the other 4 soils was positive proof of its presence there.

Sixteen boiling tubes were prepared for each soil. In order to have widely varying conditions of alkalinity and acidity, compost was used instead of pure-culture spawn. 2N acetic acid was used to acidify the compost. The pH of the acidified compost was 5·6 and that of the untreated compost was 7·4.

Eight tubes were filled with acid and eight with untreated compost for each soil. After peak-heating all the tubes, they were spawned with about ½ in. of spawn, and the tubes incubated at 25° C. After about three weeks when there was a good spawn run, the moisture treatment was included. To four acid and four untreated tubes of each batch, water was added to bring the moisture content from 71.2% to 79%. There were now four dry acid tubes, 4 moist acid tubes, 4 dry untreated tubes and 4 moist untreated tubes for each soil being tested.

In addition to these tubes two more were added, one acid and one untreated, as controls, to check the pH of the compost where the spawn had run, and where the spawn had not yet reached, before casing with the moistened soils as before.

It was found that where spawn was running, the pH in both cases had levelled up or down respectively to approximately 6·0. Where the compost was as yet free from spawn the pH of the acidified compost had changed from 5·6 to 6·7. and that of the untreated compost from 7·4. to 7·1. It would seem then that the pH values of the composts were levelling out and the attempt to compare acidified and untreated composts was unsuccessful.

The four sets of tubes were then cased with their respective soils. As the tubes to which extra water had been added appeared to be too moist, dry soil was used for casing, moistened soil was used for the remainder of the tubes. The tubes were then plugged with cotton wool and incubated at 29° C. Up to the present, truffle fruiting bodies have only appeared in the tubes cased with soils C and D. These tubes belonged to both the acid treated and the untreated groups and pH measurements prior to casing showed that the reaction pH in these two groups had been equalised. It was interesting to note however that the fruiting bodies appeared only in the tubes with the high moisture content.

When pH measurements were checked finally, the dry untreated and acid tubes had an average pH of 6·32. The moistened tubes had an average pH of 5·8. Tubes cased with soil D, which were most successful in producing truffle had an average pH dry and moistened tubes of 5·7. However, in the tubes where truffle was actually produced the average pH was 7·2,

**Table 37. Effect of moisture and pH on development of truffle**

| Treatment | No. of tubes | No. of tubes with truffle | Mean final pH without truffle | Mean final pH with truffle |
|---|---|---|---|---|
| Wet untreated | 4 | 1 | 5·9 | 7·3 |
| Wet acidified | 4 | 2 | 5·8 | 7·15 |
| Dry untreated | 4 | 0 | 6·3 | |
| Dry acidified | 4 | 0 | 6·35 | |

When truffle fruiting bodies were first observed in the tubes, the tubes were ringed where the spawn run ended. Neither the truffle mycelium nor the mushroom mycelium grew below the ring. Average pH of the compost below the ring was 7.5.

From this experiment it can be deduced that :—

1. The effect of adding acetic acid to the compost in the tubes was eliminated.
2. In the presence of additional moisture the pH of the compost fell so that instead of the moisture and acid treatments being crossed as was planned they ran parallel.
3. Truffle appeared only in the wetter compost but the results do not show whether it was the higher moisture or the lower pH in these tubes which encouraged its appearance.
4. Truffle fruiting bodies appeared to be responsible for a considerable rise in pH of the compost in their vicinity.

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# DIRECTIONS FOR MAKING M.R.A. COMPOST

## R. L. Edwards

### Preparing wheat straw

The first essential operation is to wet the straw very thoroughly : dry straw is surprisingly resistant to breakdown in composting. A very effective method of wetting baled straw, devised by Mr. B. A. Noble, is to lay the bales in a long row up to 3 deep, and to let water drip slowly on the straw from a drip-pipe. This is a pipe supplied with water through a T joint at its centre, and drilled along its top at intervals of 1-3 inches. The pipe must be levelled with wedges so that water drips evenly along its whole length. This device will wet a row of bales thoroughly in 2-3 days. It should not be left running for long after the bales are saturated, because nutrients may be washed out of the straw. We find it very useful to ferment the straw in bales before making up the stack. This is done by arranging the wet bales in a compact block and covering them with a tarpaulin. In cold weather it is helpful to place dry bales round the sides of the block.

The wet straw ferments and heats up, softening its glossy protective coat so that if more water has to be added later it will be readily absorbed, and a tighter stack can be made. This preliminary fermentation may take 7-14 days according to the state and wetness of the straw and the weather. No harm will be done by leaving the bales for an extra week. This heating sometimes partly dries the straw so that it needs watering again when the bale is shaken out, but it is always soft and takes up water easily. This treatment also starts off the growth of high temperature moulds and bacteria which will later carry out the composting process, and ensures that enough of them are present in the stack for rapid fermentation. The straw should feel wet when stacked ; if it is not it should be watered, preferably with a medium spray, before it is stacked with the activator.

There may be some latitude in the management of the compost without affecting the yield but we recommend growers to follow established practice until they are thoroughly familiar with the behaviour of the compost. Then they may find scope for improvements without much risk of failure. The following directions if followed in detail should produce a good compost.

### Stacking

Make the stack six feet wide, and ten feet long for each ton of straw to be used. Mark out the total area to be used and spread out three bales of straw for each ten foot length. This straw should have been wetted and heated as already described, shaken out loose, and watered if it was not already saturated. Then sprinkle $\frac{1}{2}$ cwt. of Activator A on each three bales of straw.

(This proportion of Activator is suitable if the bales weigh about 90 lb. each. If they are very much larger or smaller, rather more or less activator must be used in proportion, and the same with activator B if it is applied separately).

Add another three bales of straw, trample thoroughly, add ½ cwt. activator A, and so on, trampling after each layer of straw. At 25 bales per ton this process will give eight layers of straw and activator, leaving one bale to cap the stack. If activator B is to be added separately, suspend in one gallon of hot water the activator for one ton of straw, and sprinkle one pint of this with each ½ cwt. of activator A.

These activators are now available ready-mixed. Some suppliers incorporate activator B with A and C, so that only one powder (A) has to be added at stacking, and one (C) at the last turn. This saves the trouble involved in mixing small quantities of B evenly through the stack.

**Protection**

In mild still weather a good compost can be made in the open, but it is very much better to have it under cover and protected from wind. Particularly at the start it is much looser than most horse manure and a cold wind blowing through may cool it right down. It is always worth while surrounding it with dry bales of straw for the first three weeks. This steadies the temperature and also reduces the depth of the outer layer which dries and does not heat.

Turn the stack each week, moving the compost round in the usual way so that each part goes through each position in the stack. Care in this operation is just as important as it is with horse manure. The stack can be shortened and made a little narrower as its bulk decreases.

This photograph gives some indication of what can be done with M.R.A. synthetic compost. It shows the second flush in the first crop grown on M.R.A. compost by Messrs. Noble Mushrooms Ltd. The first seven weeks picking gave over 2½ lb. per sq. ft.

If the compost is too dry when turning it may be watered, but every effort should be made to get the right amount of water in the stack early. The later water is added the greater is the risk of misjudging the amount needed. After four weeks add activator C when turning, and a week later shake out the compost and make into beds. Gypsum is included in C and no more need be added. The compost may possibly be ready after four weeks if it is to be peak-heated, but the individual grower will have to decide that for himself by the usual tests for breakdown of the straw. It is highly desirable to peak-heat the compost in the beds to 120°-140° F., supplying whatever additional heat is needed to do so. This is easier if the beds are filled quickly. Compost which is not sure to be peak-heated should have five weeks in the stack.

Synthetic compost has no droppings and therefore seems rather longer than horse manure at the same stage of development. It can be filled rather wetter than is usual with horse manure. The surface of the beds dries out almost completely but this does not seem to interfere with cropping, and the beds should not be watered between filling and casing.

## THE FORMULA

ACTIVATOR A per ton of wheat straw (unwetted)

| | cwt. | lb. | | lb. |
|---|---|---|---|---|
| Dried blood (12% N) | 3 | 0 | Sulphate of potash | 14 |
| Superphosphate (18% $P_2O_5$) | 14 | | Carbonate of lime | 50 |
| Gypsum | 35 | | | |

If the dried blood has a different proportion of N, for each 1% more N, use 28 lb. less blood : for each 1% less N, use 28 lb. more blood

ACTIVATOR B per ton of wheat straw (unwetted)
(Not to be used in galvanised containers)

| | oz. | | oz. |
|---|---|---|---|
| Manganese sulphate | 12 | Iron sulphate | 12 |
| Aluminium sulphate | $2\frac{1}{2}$ | Copper sulphate | $2\frac{1}{2}$ |
| Zinc sulphate | $1\frac{1}{4}$ | Boric acid | $1\frac{1}{4}$ |
| Ammonium molybdate | $1\frac{1}{4}$ | Chromium sulphate | $\frac{1}{2}$ |
| Potassium bromide | $\frac{1}{4}$ | Potassium iodide | $\frac{1}{4}$ |

ACTIVATOR C per ton of wheat straw (unwetted)

| | lb. | | lb. |
|---|---|---|---|
| Superphosphate (18% $P_2O_5$) | 14 | Gypsum | 70 |

**QUANTITY TO BE USED.** The amount of straw needed per 1,000 sq. ft. of bed varies according to its condition. With very fresh strong wheat straw 3 tons of straw may make enough compost for 1,000 sq. ft. If the straw has been used in windbreaks and has weathered for nearly a year, as sometimes happens, 4 tons will be needed. Both the Research Station and the growers have much to learn by experience on this and other practical aspects of composting.

**In conclusion, let no grower imagine that the use of this synthetic compost makes mushroom growing easier. It does not, and we neither claim nor expect that it will. With a horse manure compost the first very important part of the work has been done by the horse, and he probably does it more consistently than ever we shall. Man-made variations start with the amount of litter used, and continue throughout composting.**

A synthetic compost is in the grower's hands from the very start, and is quite as easy to spoil as a horse manure compost. Its two great advantages are that it can be made at any time from stored materials, and it makes possible a uniformity which can rarely be attained in practice with horse manure of constantly varying quality.

Dr. J. W. Sinden, in a letter, emphasised the need for care. He wrote : " I know just what growers think about synthetic composts : that anyone can take such a formula and the first time produce prodigious crops with it. If you can only temper their enthusiasm until they have had a little experience you will accomplish much."

Further experiments are needed on the following points (and probably many others) :

1. A cheaper source of nitrogen than dried blood.
2. The best proportions and time to add superphosphate and potassium.
3. The best proportion of gypsum.
4. Which of the trace elements are really essential, and how much of each is needed.
5. Which varieties of wheat straw are best and whether they need different treatment. What other kinds of straw can be used.
6. The precise effect of peak-heating.

# PEAK HEATING A MUSHROOM HOUSE BY CALOR GAS

## R. L. Edwards

Each of our Handcraft test houses has a capacity of 5,000 cu. ft. of air and holds 720 sq. ft. of beds on six shelves. It has aluminium foil insulation and is heated by low pressure hot water pipes supplied by a Robin Hood boiler. The Barter burners used were 3′ 9″ overall length, with 3′ flame length. They were fitted with No. 320 Calor Gas jets passing a maximum of 10 cu. ft. per hour. They were mounted side by side 6″ apart in a frame 4′ long × 1′ wide × 2′ high, made of ½″ iron piping, the burners being about 4″ above the floor, with a horizontal sheet iron baffle plate 3′ × 9″ supported 1′ 6″ above the burners. There was also a vertical sheet iron screen 3′ 6″ long beside each burner along the outside of the supporting frame. The flame burned very smoothly and was less than 1″ high in spite of the very high rate of burning.

Two Barter burners were lit from Wednesday 3 p.m. to Saturday 12 noon, each burning approximately 10 cu. ft. per hour. Total estimated consumption of gas was 1,400 cu. ft. The air temperature reached 135° F. and bed temperature 120° F. for about 24 hours. The outside day temperature (in May) was about 60° F. (night 45° F.)

This gas consumption (1,400 cu. ft.) requires approximately 35,000 cu. ft. of air and produces 4,200 cu. ft. of carbon dioxide. With a house capacity of 5,000 cu. ft., slow ventilation equivalent to a change of air every 2-6 hours is needed. Excessive ventilation wastes heat. Thorough ventilation is necessary to remove carbon dioxide at the end of the heating period.

| | £ | s. | d. |
|---|---|---|---|
| **Cost :** Capital cost of two Barter burners .... .... | 8 | 5 | 8 |
| Mounting and connections .... .... .... .... | 3 | 5 | 6 |
| Regulators and taps .... .... .... .... .... | 3 | 1 | 0 |
| | £14 | 12 | 2 |
| Hire charge for four 83 lb. cylinders .... .... | 12 | 0 | 0 |
| Gas used, ¾ of four cylinders .... .... .... | 8 | 11 | 0 |

**Results :**

The first result observed was much greater uniformity at the start of cropping and this was maintained.

The final results are compared with the best previously obtained in the following table.

| | Experiment 9 | Previous best house |
|---|---|---|
| Best bed | 2·5 | 2·5 lb./sq. ft. |
| Worst bed | 1·1 | 0·1 |
| Best group of similar beds | 2·3 | 2·1 |
| Whole house | 2·05 | 1·1 |

Standard error (a measure of the variation between individual beds receiving the same treatment).

| | | |
|---|---|---|
| Of yield, % of average | 11% | 36% |
| Of spawning-picking interval | 1·7 days | 7·5 days |

The striking feature is the very great decrease in variation between similar beds. Peak-heating reduces the risk of failure and evens out the yields in successive crops by improving some of the lower yields.

Experiment 9 included 72 beds filled from 24 separate stacks composted for four different periods (3-6 weeks) so that there was plenty of scope for variations in yield to occur and it would be expected to show some of the variation which growers experience over a series of 24 crops.

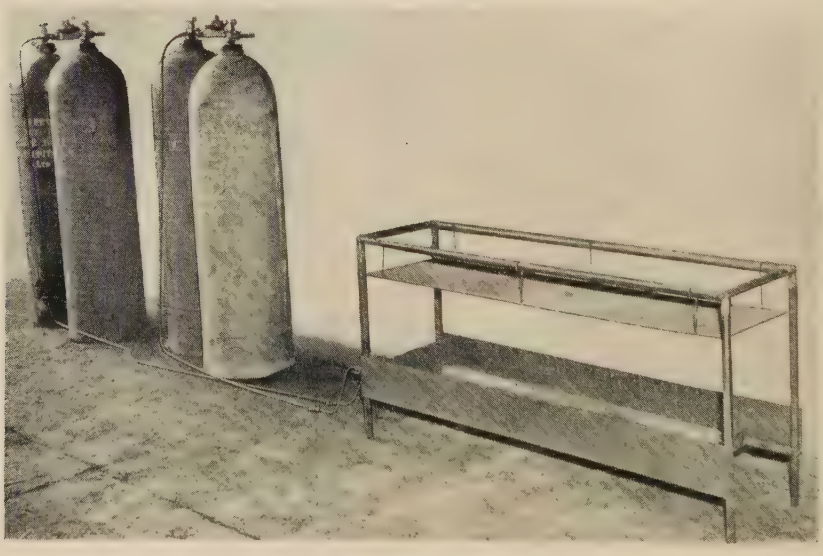
The test was uncontrolled but we are convinced that the heat treatment was responsible for much of the improvement in uniformity and yield compared with previous crops.

The effect of peak-heating on the under-done compost was interesting and will be described, when all the results have geen worked out, in the M.R.A. Annual Report for 1949.

A similar house was peak-heated in the same way in December, 1949, when the outside temperature was about 32-35° F. day and night. Four cylinders of gas were consumed in 96 hours. The air temperature was 125° F. for 48 hours and the bed temperatures 120-130° F.

Calor gas cylinders, burners, control valves, etc., are supplied by the Calor Gas Distributing Co. Ltd., Belgrove House, Belgrove Street, London, W.C.1, through local agents in all districts. Enquiries should be addressed for the attention of Mr. S. Shaw, Distribution Department.

The frame work in which the burners were mounted at Yaxley was supplied by The Boroughbury Engineering Co. Ltd., Lincoln Road, Peterborough, Northants.



Calor Gas installation used in M.R.A. test house.

# WHAT DOES YOUR COMPOST COST?

## R. L. Edwards

Falling prices of mushrooms have fixed growers' attention much more closely on costs during the past year and one of the main costs of growing mushrooms is the compost. It is the usual custom to talk about the cost of manure, or of the ingredients in a synthetic compost, as a price per ton and to describe the yield of mushrooms obtained in pounds per square foot, cheerfully ignoring the fact that there may be a very big difference in the bed area filled by a ton of different kinds of manure. What matters to the grower is the cost of compost in the bed per pound of mushrooms produced. This is automatically reduced by increasing the yield per square foot, by any means which does not add to the cost of the compost, but that is not the point of this discussion.

The cost of compost is made up of two parts, (*a*) the cost of the materials, (*b*) the labour cost preparing it. In the examples which follow arbitrary figures have been taken for the initial cost of manure and for the labour, cost of turning etc. These will certainly not apply to all growers, they may not apply exactly to any, but readers can replace them by their own working costs and so make similar calculations for themselves. The main conclusions as to the relative importance of manure and labour and the comparison between light and heavy manure are unlikely to be very much changed when this is done.

Let us deal with (*a*) first. It is natural to regard a ton of manure as a ton of manure, it varies in quality perhaps, but it is still a ton of manure. **Nothing can be more misleading.** Heavy stable manure is usually delivered with about 75% of moisture, light strawy manure often has only 50%. This does not sound a very big difference, but if we look at the dry matter for which we are really paying, the heavy manure has 25% and the light manure 50%, exactly twice as much. We like to stack manure with about 75% of water. When light manure is watered up to this level its weight is doubled, so light manure with 50% dry matter priced at £3 per ton is reduced to 30/- per ton calculated on the wet stack, which is what matters to the grower. The following are examples of the cost :

### Cost of compost materials

1. Heavy transport stable manure at £4 per ton, delivered, containing 75% moisture.

   1 ton fills 50 sq. ft. Cost £80 per 1,000 sq. ft.

2. Light long straw stable manure at £3 per ton, delivered. Containing 50% water.

   When watered up to 75% moisture this is doubled in weight.

   1 ton as stacked fills 60 sq. ft. Cost £25 per 1,000 sq. ft.

3. M.R.A. Synthetic Compost.
   1 ton of straw at £3 per ton, delivered.
   4 cwt. of activator 'A' at 47/- per cwt. delivered.
   84 lb. of activator ' C ' at 14/- per cwt., delivered.
   (Activator ' B ' can now be incorporated in 'A' and ' C ')
   Total cost £12 18s. 0d. for 23 cwt. dry matter, making 92 cwt. with 75% of moisture.
   1 ton as stacked fills 70 sq. ft. Cost £40 per 1,000 sq. ft.

There is an another alternative—the addition of activators to the light manure. Some examples are given below, with approximate costs.

4. M.R.A. activator at $\frac{1}{4}$ standard rate for straw, i.e. 42 lb. of 'A' and 10 lb. of ' C ' per ton of manure stacked, filling 60 sq. ft.
   Cost of activators £15 per 1,000 sq. ft.
   Total cost of manure £40 per 1,000 sq. ft.

5. Adco M at 28 lb. per ton of manure stacked, filling 60 sq. ft.
   Cost of Adco M £7 7s. 0d. per 1,000 sq. ft.
   Total cost of manure £32 per 1,000 sq. ft.

6. Poultry manure at 1 cwt. per ton of manure stacked, filling 60 sq. ft.
   Cost of supplement £20 per 1,000 sq. ft.
   Total cost of manure £45 per 1,000 sq. ft.

The quantities of M.R.A. activator and Adco M quoted above are those suggested by their sponsors. The quantity of poultry manure is believed to represent typical commercial practice. Ideally, the quantities should be adjusted to the quality of each batch of manure according to the grower's judgement.

The economic question facing the grower is whether the more expensive compost gives enough additional mushrooms to pay for the difference in price. How much is needed ? If we take a fairly low average sale price and allow for the cost of picking and packing, we might estimate the value of mushrooms as grown but not packed at 2 6 per lb. The heavy manure costs £55 per 1,000 sq. ft. more than the light, which would be paid for by 440 lb. of mushrooms, or 0·44 lb. per sq. ft.

Fortifying the light manure will pay if the increase in yield is over 0.12 lb. per sq. ft. with M.R.A. activators, 0·064 lb. per sq. ft. with Adco M, or 0·16 lb. per sq. ft. with dried poultry manure. These figures fall if the price of mushrooms goes up and vice versa. With very long strawy manure there is an excellent chance that these increases will be obtained, and manure of this type should always pay handsomely for the use of one of these activators.

It is much more difficult to decide which of them is best, and whether any of them is economically superior to the heavy manure on the one hand, or plain M.R.A. compost on the other. These questions can only be finally decided on the basis of repeated yield tests.

**Cost of synthetic compost**

Ever since the M.R.A. Report appeared in April, 1949, growers have been asking for a cheaper source of nitrogen than dried blood. Some of the possible alternatives are shown in the following table. The cost of

dried blood as now used is 6d. per sq. ft. of bed, equivalent to about 1/5th lb. of mushrooms, so that is the absolute limit of the possible saving in cost. It is not worth using anything which gives a yield measurably lower than that from dried blood. The table shows the nitrogen content and amount of each fertiliser needed, prices which have been quoted, and the cost and possible saving per 1,000 sq. ft. of bed compared with dried blood.

**Sources of nitrogen for use with straw, supplying total N equivalent to 3 cwt. dried blood per ton of straw.**

| Material | N% | Cwt./ton straw needed | Cost per ton | Cost per 1,000 sq. ft. | Poss.saving per 1,000 sq. ft. |
|---|---|---|---|---|---|
| | | | £ | £ | £ |
| Dried blood .... .... | 12 | 3 | 50 | 22 | |
| Urea .... .... .... | 45 | ¾ | 14 | 2 | 20 |
| Ammonium sulphate .... | 20 | 1¾ | 14 | 4 | 18 |
| Nitrochalk .... .... | 15 | 2¼ | 15 | 5 | 17 |
| Cyanamide .... .... | 20 | 1¾ | 21 | 6 | 16 |
| Shoddy manure .... | 7 | 6 | 8 | 7 | 15 |
| Hide and leathermeal .... | 6·5 | 6 | 11 | 10 | 12 |
| Soluble hide meal .... | 6·5 | 6 | 12 | 11 | 11 |
| Shoddy manure .... | 12 | 3 | 25 | 11 | 11 |
| English meat meal .... | 13 | 2¾ | 33 | 14 | 8 |
| Hoof and horn meal .... | 14 | 2½ | 40 | 15 | 7 |
| Fish guano .... .... | 8 | 5 | 28 | 21 | 1 |
| Dried poultry manure .... | 5 | 10 | 25 | 38 | costs more |

Of these alternatives, ammonium sulphate and nitrochalk have been tried unsuccessfully, and there are technical reasons for thinking that urea and cyanamide will probably behave in a similar way. However, the possible saving in cost is so great that they are worth testing. Shoddy manure is extremely difficult to mix with other fertilisers in a mixed activator, or with straw in a compost heap. Meat meal contains more phosphate than is needed, and although this is not as soluble as that in superphosphate, its effect is unknown. Soluble hide meal has given a fair result in one test which needs repeating.

Hoof and horn meal and hide and leather meal are the only others which would show a saving, so that this group—hoof, horn, hide, leather—is the only one at all likely to replace dried blood, at a saving of £7-£12 per 1,000 sq. ft.

Dried blood accounts for over half the cost of synthetic compost, and straw for about one quarter. There is little scope for saving on the other materials used, so the best we can hope for is that materials for our synthetic compost may come down to about £30 per 1,000 sq. ft., compared with £25 for plain racing stable manure.

An estimate of the cost of labour for composting is set out below. Some growers may use less labour, and others more than is represented by these figures, but they provide a working basis for comparisons.

| | | | | | | |
|---|---|---|---|---|---|---|
| Stacking horse manure | £3 | per | 1,000 | sq. | ft. | to be filled. |
| Stacking synthetic compost | £4 | ,, | ,, | ,, | ,, | ,, |
| Turning compost | £3 | ,, | ,, | ,, | ,, | ,, |
| Mixing and filling | £5 | ,, | ,, | ,, | ,, | ,, |

Thus to stack, turn three times, mix and fill costs about £17 per 1,000 sq. ft. The saving by omitting one turn is £3 per 1,000 sq. ft.

It is clear that small savings, but not large ones, can be made by economy in turning, but there is a possible further saving to be obtained in this way since a reduction in the number of turns also reduces the breakdown and enables a ton of manure to fill a larger area.

Finally, many growers use supplementary heating to ensure a satisfactory peak heat in their beds. An estimate of the cost of such heating for our houses is given below and it is clear that a very small increase in yield is sufficient to pay for this additional cost of heating. The exact cost depends on the type of house, main heating system, condition of compost, etc.

**Cost of supplementary heat for peak heating**

By Calor gas approximately £4 per 1,000 sq. ft. per day.

There may be other factors such as overhead charges which make high yields more profitable, but they are complex and vary too much between farms to discuss them here.

To summarise :—

The first essential in looking for economies is to know where money is being spent. Compost and the labour of preparing it must form the largest single item and at least a third of the total cost of mushroom growing. Although the actual figures used here cannot apply to all growers they show the general trend, and any grower who is sufficiently interested can make similar calculations with his own prices and labour costs.

# THE USE OF INDICATOR PAPERS FOR pH TESTS ON COMPOST & SOIL

S. Burrows

There has recently come on to the market a new series of " Close Range Indicator Papers " which may be of considerable use for testing the pH of compost and soil at a trifling cost and without the irritating delay which occurs when samples are sent away for testing. The results obtained are only approximate (within 0·5 pH unit above or below the true value) but they will usually tell the grower what he wants to know—that is, when the compost pH has dropped below 8 or if the soil pH is between 7 and 8. We should like to emphasise here that soil to which hydrated lime has just been added will have a very high pH and no useful information will be gained by testing it until it has weathered for a few weeks.

The indicator papers are supplied in a number of grades for different pH ranges but the most suitable grades for growers are :—

Johnson's Comparator Test Books No. 5267 (pH range 5·2—6·7)
" " " " No. 6883 (pH range 6·8—8·3)

The books should be kept in a small tin box away from fumes of any kind especially ammonia from the compost heap. The papers change colour when moistened with liquid, the exact shade of colour produced depending upon the pH of the liquid. This colour is then matched against the colour chart inside the cover of each book, where shades of colour and the corresponding pH in steps of 0·3 are given.

**Method for testing pH compost**

Take a handful of compost, divide it in two and press one indicator paper between the two halves until it is just moistened. Do not leave the paper until it is sodden or the brown liquid in the compost may obscure the colour of the paper. Remove the paper and match the colour of the moist patches against the shades on the colour chart. Note the pH, repeat the operation with handfuls of compost from other parts of the heap or bed and take the average. Growers are advised not to rely on tests done just before filling but to test also at one or two previous turns so as to make sure that the pH is not rising.

**Method for testing pH of soil**

Mix the soil with a little water in a clean container until a thin paste is obtained. It is preferable to use distilled water (from a chemist's shop, **not** a garage) rather than tap water which may alter the pH somewhat. Leave the mixture about fifteen minutes, stir well and dip the end of an indicator paper into it. Remove it quickly and shake or brush off the soil adhering to it. Match the colour of the paper against the colour chart. Repeat the whole operation for samples of soil from different parts of the heap or batch of soil.

It is very important to remember that the pH alone is not a sufficient indication of the suitability of compost or soil, but must be taken in conjunction with all the other indications which growers are in the habit of using.

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